PB80-198997

Systems Approach to Beach Protection for Oil Spill Incidents. Phase I. Feasibility Study

RRC International, Inc.
Latham, NY

Prepared for

Industrial Environmental Research Lab.
Cincinnati, OH

Oct 75

U.S. Department of Commerce
National Technical Information Service
NTIS.

BEGIN FIRST LINE OF TEXT HERE
TYPING GUIDE SHEET
CENTER OF PAGE
TOP OF IMAGE AREA
DROPPED HEAD: BEGIN SECTIONS HERE
6-1/2"
9-1/8"

PB80-198997

EPA-600/2-80-150
June 1980

SYSTEMS APPROACH TO BEACH PROTECTION FOR OIL SPILL INCIDENTS

Phase I. Feasibility Study

by

Paul E. Bakeman, Jr.
Albert L. Armstrong
RRC Internation Inc.
Latham, New York 12110

Grant No. R-803087-01-0

Project Officer

Leo T. McCarthy, Jr.
Oil and Hazardous Materials Spills Branch
Industrial Environmental Research Laboratory
Edison, N.J. 08817

Industrial Environmental Research Laboratory
Office of Research and Development
U.S. Environmental Protection Agency
Cincinnati, Ohio 45268

REPRODUCED BY
NATIONAL TECHNICAL INFORMATION SERVICE
U.S. DEPARTMENT OF COMMERCE
SPRINGFIELD, VA 22161

BEGIN LAST LINE OF TEXT
BOTTOM OF IMAGE AREA, OUTSIDE DIMENSION FOR TABLES AND ILLUSTRATIONS
3/8"
PAGE NUMBER
EPA-287 (Cin.)
(4-76)

BIBLIOGRAPHIC INFORMATION

PB80-198997

Systems Approach to Beach Protection for Oil Spill Incidents. Phase I. Feasibility Study,

Oct 75

Paul E. Bakeman, Jr., and Albert L. Armstrong.

PERFORMER: RRC International, Inc., Latham, NY.
Grant EPA-R-803087-01

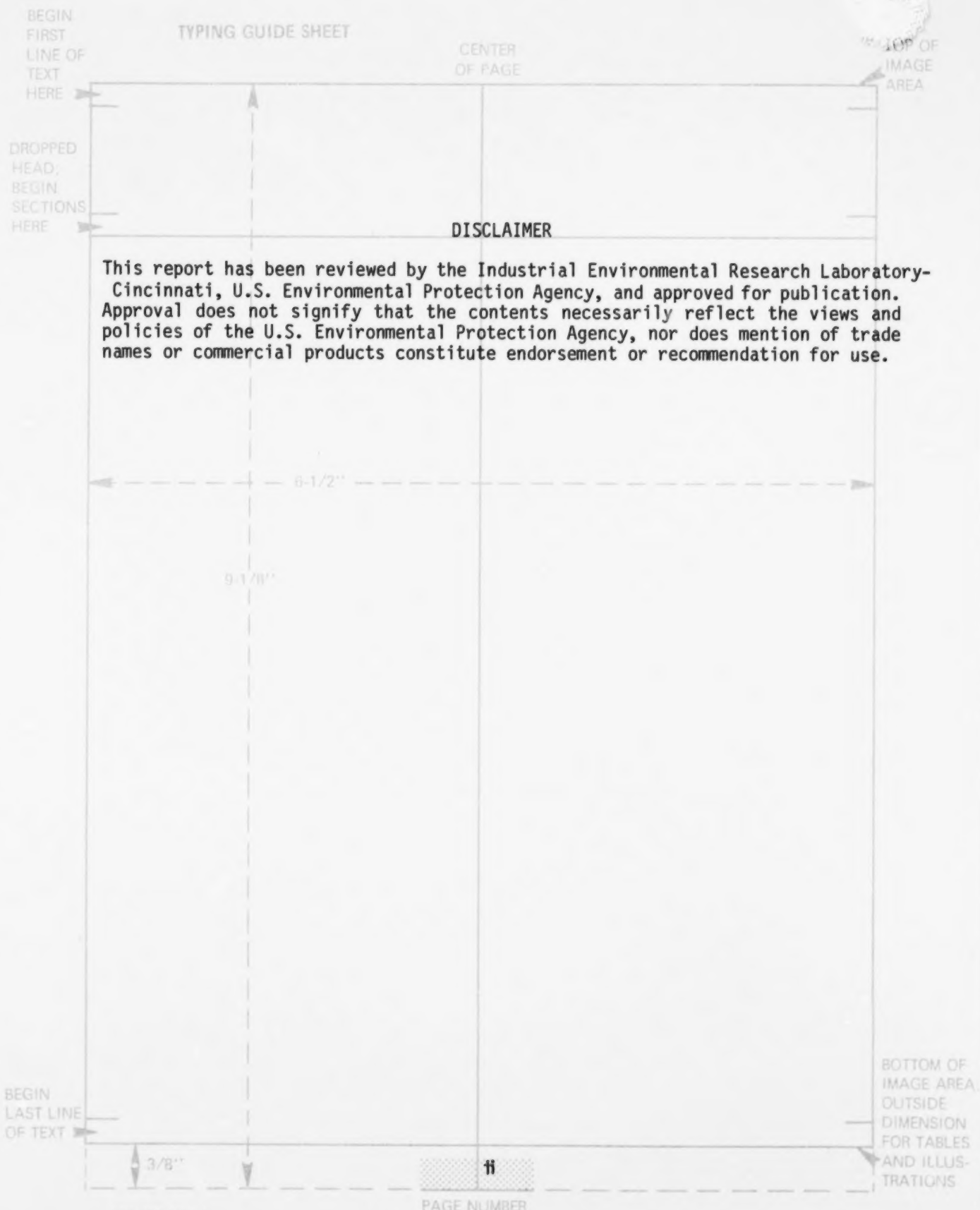
SPONSOR: Industrial Environmental Research Lab.-Cincinnati, OH.

This report is a product of the above efforts. The beach protection system studied in this program is designed to limit the environmental damage caused by oil spills originating from oil exploration, production and transportation. A sorbent-based beach protection system has been investigated and tested for deployment on shorelines and within the intertidal zones of beaches.

KEYWORDS: *Crude oil, *Beaches, *Shore protection, *Oil spills.

Available from the National Technical Information Service, Springfield, Va. 22161

PRICE CODE: PC A04/MF A01



DISCLAIMER

This report has been reviewed by the Industrial Environmental Research Laboratory-Cincinnati, U.S. Environmental Protection Agency, and approved for publication. Approval does not signify that the contents necessarily reflect the views and policies of the U.S. Environmental Protection Agency, nor does mention of trade names or commercial products constitute endorsement or recommendation for use.

BEGIN FIRST LINE OF TEXT HERE
TYPING GUIDE SHEET
CENTER OF PAGE
TOP OF IMAGE AREA
DROPPED HEAD; BEGIN SECTIONS HERE

FOREWORD

When energy and material resources are extracted, processed, converted, and used, the related pollutional impacts on our environment and even on our health often require that new and increasingly more efficient pollution control methods be used. The Industrial Environmental Research Laboratory Cincinnati (IERL-Ci) assists in developing and demonstrating new and improved methodologies that will meet these needs both efficiently and economically.

This report is a product of the above efforts. The beach protection system studied in this program is designed to limit the environmental damage caused by oil spills originating from oil exploration, production and transportation. A sorbent-based beach protection system has been investigated and tested for deployment on shorelines and within the intertidal zones of beaches. This project is part of the continuing program of the Oil and Hazardous Materials Spills Branch, IERL-Ci, to assess and mitigate the environmental impact of oil pollution.

David G. Stephan
Director
Industrial Environmental Research Laboratory
Cincinnati

BEGIN LAST LINE OF TEXT
BOTTOM OF IMAGE AREA OUTSIDE DIMENSION FOR TABLES AND ILLUSTRATIONS
3/8"

EPA-287 (Cin.)
(4-76)

BEGIN FIRST LINE OF TEXT HERE
TYPING GUIDE SHEET
CENTER OF PAGE
TOP OF IMAGE AREA
DROPPED HEAD; BEGIN SECTIONS HERE

ABSTRACT

A major portion of the damage caused by an oil spill occurs at the beach or intertidal zones. With the advent of modern forecasting procedures, it has become possible to predict in advance which beach areas will be affected in the event of an oil spill. Thus, the beach represents an area where effective measures should be applied to minimize or prevent the occurrence of damage.

The system presented in this report is based on applying a sorbent blanket especially designed for the purpose to the appropriate beach area before the arrival of the oil contamination. This application will normally be performed with the aid of an ATV (all terrain vehicle) modified for this function. This same vehicle also rerolls the blanket and, in the process, extracts the absorbed oil using pinch rollers and collection pans. This permits reuse of the sorbent blankets.

This report details the specification, evaluation, fabrication, and experimentation of sorbent blankets for beach protection use. Included is the design of a modified ATV to aid in performing the task of beach protection. Also presented are the results of on-site testing at Woodbridge, New Jersey, of a feasibility scale demonstration.

This report was submitted in fulfillment of Project No. R-803087-01-0 under the sponsorship of the Environmental Protection Agency. Work was completed as of October 1975.

BEGIN LAST LINE OF TEXT
BOTTOM OF IMAGE AREA; OUTSIDE DIMENSION FOR TABLES AND ILLUSTRATIONS
3/8"

PAGE NUMBER
EPA-287 (Cin.)
(4-76)

BEGIN FIRST LINE OF TEXT HERE
TYPING GUIDE SHEET
CENTER OF PAGE
TOP OF IMAGE AREA
DROPPED HEAD; BEGIN SECTIONS HERE
6-1/2"
BEGIN LAST LINE OF TEXT
3/8"
BOTTOM OF IMAGE AREA; OUTSIDE DIMENSION FOR TABLES AND ILLUSTRATIONS
PAGE NUMBER
EPA-287 (Cin.)
(4-76)

CONTENTS

Foreword		iii
Abstract		iv
Figures		vii
Tables		vii
i Acknowledgment		viii
I	Introduction	1
II	Conclusions	3
III	Recommendations	5
IV	Sorbent Mat Considerations	6
	Introduction	6
	Designed Implementation	6
	Environmental Compatibility	7
	Laboratory Testing	9
	Oil, Sand and Water	9
	Structural Composition	10
	Turbulence Assisted Adsorption	10
	Microfibrous Polypropylene	10
	Polypropylene Foam	10
	Sand Clean-Up With Sorbents	10
	Oil-Water Stratification in Urethane	11
	Sorbent Selection for Feasibility Demonstration	11
	Support Web	11
	Anchors	12
	Fabrication Methods	13
	Adhesive Bonding	13
	Thermal Bonding	14
	Mat Improvements for Second Test Demonstration	15
	Sealed Sorbent	16

BEGIN FIRST LINE OF TEXT HERE
TYPING GUIDE SHEET
CENTER OF PAGE
TOP OF IMAGE AREA
DROPPED HEAD: BEGIN SECTIONS HERE

CONTENTS (cont'd)

V	Beach Protection Vehicle Requirements	19
	Approach	19
	Vehicle Design Objectives	20
	Vehicle Modifications	21
	Operation and Maintenance	23
	Squeeze Roller Take-Up Reel Operation	24
	Loading and Cleaning	24
	Removal and Disassembly	25
	Adjustments	25
	Fuel	26
	Lubrication and Maintenance	26
VI	On-Site Test Demonstrations	27
	Test Site Description	27
	Site Selection	28
	Site Preparation	28
	Object of On-Site Tests	29
	Conduct of First On-Site Test	29
	Results and Observations from First On-Site Test	33
	Anchors and Anchoring System	33
	Beach Protection Mat Response	34
	Deployment and Recovery Time Factors	35
	Vehicle Operation	36
	Second On-Site Test	38
	Conduct of Second On-Site Test	38
	Observations from Second On-Site Test	41
	Beach Protection Mat Performance	41
	Anchors and Accessories	42
	Vehicle Performance Observations	42
	Operational Observations	43
VII	References	45

BOTTOM OF IMAGE AREA OUTSIDE DIMENSION FOR TABLES AND ILLUSTRATIONS
BEGIN LAST LINE OF TEXT
3/8"

PAGE NUMBER
EPA-287 (Cin.)
(4-78)

FIGURES

Number		Page
1	Ajax Screw--In Anchor	13
2	Thermally Bonded Test Mat, Polyethylene and Polyurethane	15
3	Grommet-Type Anchor Point Design	17
4	Unsealed Grommetted Mat on Beach Protection Vehicle	18
5	Beach Protection Vehicle Before Second On-Site Test	23
6	Screw-In Anchor Insertion and Removal	44
7	Threading A Beach Protection Mat Into The Modified Vehicle	44

TABLES

Number		Page
1	Sorbent Materials Evaluated	8
2	First Site Demonstration Projected Tests	30
3	Tide Table for Sandy Hook, New Jersey - First Site Test	32
4	Tide Table for Sandy Hook, New Jersey - Second Site Test	39

BEGIN FIRST LINE OF TEXT HERE
TYPING GUIDE SHEET
CENTER OF PAGE
TOP OF IMAGE AREA
DROPPED HEAD: BEGIN SECTIONS HERE

ACKNOWLEDEMENTS

The aid of Mr. Eugene DeStefano and the Township of Woodbridge in providing the interest in making this work possible is greatly appreciated. The excellent cooperation and assistance provided by the Township of Woodbridge at the on-site tests is also appreciated.

The assistance, encouragement, and helpful suggestions provided by Mr. David Longstreet of the New Jersey Department of Environmental Protection is also acknowledged.

Our subcontractor, Independent Associates of Buffalo, New York, was extremely helpful in designing and implementing the extensive vehicle modifications needed by the beach protection vehicle.

Finally, the advice and assistance of our project officer, Mr. Leo McCarthy, is gratefully acknowledged.

BEGIN LAST LINE OF TEXT
BOTTOM OF IMAGE AREA: OUTSIDE DIMENSION FOR TABLES AND ILLUSTRATIONS
3/8"

PAGE NUMBER
EPA-287 (Cin.)
(4-76)

BEGIN FIRST LINE OF TEXT HERE
TYPING GUIDE SHEET
CENTER OF PAGE
TOP OF IMAGE AREA
DROPPED HEAD; BEGIN SECTIONS HERE

I. INTRODUCTION

Considerable damage is incurred to coastal and inland shorelines annually because of contamination caused by accidental oil spill incidents. The spills occur in all phases of oil handling and include exploration, transport, and transfer of materials with properties varying from viscous No. 6 oil to highly refined finished products. Biological effects of such spills are considerable, as much marine life uses estuaries and intertidal zones as spawning grounds.[1] A bibliography of material entitled "The Biological Effects of Oil Pollution"[1] includes numerous papers dealing with biological damage of oil spills. Reference 2 in particular presents the long-term biological effects of the West Falmouth Oil Spill. In addition to biological factors, there is considerable economic damage incurred when shorelines are made unusable by oil spill contamination.[3,4] It is, as a consequence, very important to develop methods and techniques to prevent oil spill damage from occurring to beaches and to clean up the damage once it has occurred.

Past efforts in this regard have centered around two major approaches. The first is to contain the oil spill once it has occurred to prevent it from reaching beach areas that would otherwise become contaminated. The second is to clean up the contaminated beach material after the damage has taken place. In addition, operational procedures, regulations, and equipment designs have been revised to minimize the occurrence and size of oil spill incidents.

Containment generally includes booms surrounding the oil spill in open water or across stream surfaces inland which restrain the surface flow of oil sufficiently long that skimming or sorbent recovery techniques may be used to remove the oil from the water surface. A number of booms and barrier systems are currently available and are presented in reference 5, 6, and 7. References 5, 8, 9, 10, 11 and 12 present sorbent and skimmer systems used to remove the oil-spill layer from the water surface. However, booms are effective only under certain conditions. Currents, winds, and waves will limit a boom's effectiveness and the timeliness of deployment will in part determine how much oil will pass by the boom.

The second approach is mechanical clean up of the beach after contamination has occurred. In this respect, studies have been made determining the effectiveness of removing and transporting or cleaning contaminated sand beaches. Reference 13 uses froth flotation cleaning, whereas reference 14 presents data on a sand washing cyclone separator process. Reference 15 evaluates the cost and suitability of earth moving equipment required to feed beach cleaners or to cart away contaminated material for inland disposal. Reference 16 examines the feasibility of using an incineration process to clean oil contaminated beach sand. Although most of the above references strive to provide portability of the cleaning

BEGIN LAST LINE OF TEXT
BOTTOM OF IMAGE AREA, OUTSIDE DIMENSION FOR TABLES AND ILLUSTRATIONS
3/8"

PAGE NUMBER
EPA-287 (Cin.) (4-76)

systems, the systems presented are large by their very nature and may present transportation and logistics problems in reaching an oil spill site. Also, because of their size, large systems are much better suited to application on isolated, massive spills rather than on numerous small spills, which also cause much damage.

The current work is directed toward developing a beach protection system capable of being deployed rapidly on a beach or shoreline that is endangered by an oil spill. The object is to prevent damage to the beach site by affording protection at the land-water boundary itself. The system includes beach protection mats designed to be compatible with the sand-oil-water environment as well as the stringent physical requirements of the beach interface. Also included is a modified ATV (all terrain vehicle) which is used as an aid in deployment, as a method of picking up the mat and removing retained oil and water, and as a method for rolling up the mats after the oil spill incident has terminated. One vehicle can be used with many mats, and in cases where a vehicle is not available, manual deployment is feasible, with the vehicle being used later to aid in mat pickup and cleaning procedure.

The purpose of the current work is to:

1. Develop beach protection mats and anchoring and deployment methods.

2. Develop modifications for an all terrain vehicle (ATV) to assist in deployment and pickup.

3. Demonstrate the feasibility of the system in a small scale test site demonstration in the Township of Woodbridge, New Jersey.

BEGIN FIRST LINE OF TEXT HERE
TYPING GUIDE SHEET
CENTER OF PAGE
TOP OF IMAGE AREA
DROPPED HEAD. BEGIN SECTIONS HERE

II. CONCLUSIONS

The feasibility of developing a beach protection system to be activated in the event of an oil spill incident was investigated. The effort was directed toward using sorbent mat structures applied to the beach surface in the intertidal zone. Sorbent mats were designed, fabricated, and tested at a test site beach. An anchoring system was also designed and beach site tested. Modifications to an ATV were developed and implemented to aid in deploying squeeze roller cleaning, re-rolling, and transporting beach protection mats. The vehicle was also beach-site tested.

Primary conclusions reached during this feasibility study are:

1. The application of structurally reinforced mats anchored to a beach surface is feasible at least in cases of limited turbulance.

2. Sorbent materials meeting all the enviromental and structural requirements of beach application are not commerically available.

3. Reusable beach protection mats are required by the application because of the additional cost imposed by reinforcement and anchoring requirements.

4. The three 30 meter by 1.22 meter beach protection mats, designed and fabricated for the feasibility study, performed well at the beach site tests. Improvements in mat design to provide additional strength are recommended.

5. The thermal bonding process developed to bond polyurethane sorbent material to the polyethylene support web produced strong bonds which did not deteriorate under laboratory oil and water tests or at beach site tests.

6. Two types of anchors were found which are well suited to beach protection use. They are drive point anchors and screw-in anchors. Improvements in anchors designed for beach protection use are possible.

BEGIN LAST LINE OF TEXT
BOTTOM OF IMAGE AREA; OUTSIDE DIMENSION FOR TABLES AND ILLUSTRATIONS
3/8"

EPA-287 (Cin.)
(4-76)

BEGIN FIRST LINE OF TEXT HERE
TYPING GUIDE SHEET
CENTER OF PAGE
TOP OF IMAGE AREA
DROPPED HEAD; BEGIN SECTIONS HERE
BEGIN LAST LINE OF TEXT
BOTTOM OF IMAGE AREA; OUTSIDE DIMENSION FOR TABLES AND ILLUSTRATIONS
3/8"
PAGE NUMBER
EPA-287 (Cin.)
(4-76)

7. Power aided insertion and removal of both types of beach protection anchors is both feasible and reccomended for use in an emergency response system.

8. The modified ATV successfully performed the four functions for which it was designed: mat layout, pick-up, cleaning; and transport.

9. The small size of the components of the beach protection system, including the vehicle, is an asset, especially in situations where it is desired to respond to smaller spills or where it is desired to have a rapid response capability in a number of locations.

10. On-site tests demonstrated the strengths and weakness of various portions of the beach protection system. Additional concerted effort is needed to transform the system from a successful feasibility study to useful capability to be applied to the task of protecting our environment.

11. Although the objective of this work was to examine the feasibility of protecting beaches from oil spill damage, it is concluded that the reinforced sorbent materials and handling methods which have been developed might be applied with success to other environmental situations.

BEGIN FIRST LINE OF TEXT HERE
TYPING GUIDE SHEET
CENTER OF PAGE
TOP OF IMAGE AREA
DROPPED HEAD; BEGIN SECTIONS HERE

III. RECOMMENDATIONS

Based on the results of this feasibility study research effort, it is recommended that continued effort be applied to develop the feasibility beach protection system into an operational beach protection system. The importance of expediency cannot be over emphasized in light of the increased transportation of and exploration for oil anticipated in the near future. It is recognized that no single approach to handling oil spill incidents will be universally applicable to all spills. A number of protection and clean up systems must be available to be applied to control oil spill damage wherever they are appropriate. Thus, booms, skimmers, chemicals, and beach cleaning equipment, as well as the sorbent based beach protection system examined in this research effort, are needed to effectively and economically protect our environment from future oil spills.

The major areas of effort required to develop the sorbent based beach protection system into a usable capability are as follows:

1. Perform further research and development on the materials, processes and equipment used in the beach protection system. All system components must be made effective, reliable and economical.

2. Develop specifications for material procurement and production. Interact with manufacturers and develop commercial availability of all system components.

3. Perform expanded site tests to evaluate both the oil effectiveness of the system and its environmental limitations (surf height, etc.).

4. Develop an operable response capability to be tested on an oil spill occurring during the research and developmental effort.

It is recommended that work on the areas presented above be undertaken to develop a sorbent based beach protection response capability.

BEGIN LAST LINE OF TEXT
BOTTOM OF IMAGE AREA; OUTSIDE DIMENSION FOR TABLES AND ILLUSTRATIONS
3/8"

PAGE NUMBER
EPA-287 (Cin.)
(4-76)

BEGIN FIRST LINE OF TEXT HERE
TYPING GUIDE SHEET
CENTER OF PAGE
TOP OF IMAGE AREA
DROPPED HEAD; BEGIN SECTIONS HERE

IV. SORBENT MAT CONSIDERATIONS

INTRODUCTION

Considerable effort has been applied to the task of determining the materials, design and construction techniques suitable for the beach protection mat. The factors involved include structural design, anchoring techniques, environmental compatibility, re-usability, sorbent materials selection, fabrication processes, storage considerations and cost. The prime goal of this project is to demonstrate the feasibility of protecting a beach, at the water-land boundary, from contamination due to an oil spill. Guidelines for the range of oils against which there is to be protection are No. 2 to No. 6 and in an ambient temperature environment of from near freezing to approximately 32°C (90°F). It should be remembered that the goal is to protect the beach from oil contamination rather than to be the prime method for removing oil from the water surface. In this respect, on thin oil spills, the sorbent mat may be all that is needed to protect the beach from permanent degradation. However, on thicker spills, the use of booms, skimmers, sorbents, and so forth in open water, in cooperation with beach protection mats on the shoreline, would be highly desirable.

The beach protection mats are envisioned to possess four distinct parts or characteristics. First, there must be a material that either prevents oil from reaching the beach surface or absorbs oil from the beach surface and the water or both. Second, the mats must be capable of withstanding the forces of wave action at a shore boundary. Thus, either the sorbent must be strong or a second reinforcing web must be part of the mat structure. Third, the mat must be anchorable to the shoreline. It must have sufficient strength to allow staking or must have reinforced regions to permit anchoring lines to be attached to anchors in the beach. Fourth, the mat structure must be resistant to mechanical or chemical disintegration during use. In general, this requirement specifies that all portions of the mat be chemically or mechanically bonded together such that no loss of material occurs during normal use.

DESIGNED IMPLEMENTATION

The beach protection mats developed and demonstrated during this program are designed to be anchored at the anticipated high tide water mark with parallel mats extending toward the low tide water line. In the case of inland water, where no tide exists, the mats should be layed between the anticipated wave action high water line and the calm water shoreline, thus, protecting the area where oil contamination is most severe.

BOTTOM OF IMAGE AREA; OUTSIDE DIMENSION FOR TABLES AND ILLUSTRATIONS
BEGIN LAST LINE OF TEXT

3/8"
PAGE NUMBER
EPA-287 (Cin.) (4-76)

BEGIN FIRST LINE OF TEXT HERE
TYPING GUIDE SHEET
CENTER OF PAGE
TOP OF IMAGE AREA
DROPPED HEAD; BEGIN SECTIONS HERE

ENVIRONMENTAL COMPATIBILITY

The environment of a beach or shoreline is considerably different from that of an open water region. In particular, the beach involves sand, rocks, shells, and other solids, in addition to water and oil during an oil spill incident. Further, there may be tides depending upon the location of the body of water. Also, the turbulence and shear forces due to wave action are much different along a shore than in open water. These environmental factors must be considered if the mat is to operate successfully on the beach.

The beach protection application entails the same general requirements for the sorbent material as are found in open water applications with the addition of two factors:

1. The sorbent must be compatible with a sand containing environment.

2. The sorbent must retain oil in more turbulent water, and must remain attached to the supporting medium when in a turbulent environment.

These factors restrict considerably the types of sorbent materials which are suited to the beach protection task. Many materials are excellent sorbents when used in open water or still water, but simply do not possess the strength or oil retention capability to be well suited for beach protection use. Still others have sufficient strength but would allow sand as well as oil to be picked up, making cleaning or removal and disposal very difficult.

Table 1 shows a list of sorbent materials which were evaluated as part of this program. The materials are commercially available and were obtained in small quantities for laboratory testing. Manufacturers were located primarily from reference 5 with additional manufacturers located through reference 17. All materials obtained from the manufacturers were evaluated as to their suitability for the range of oil and environmental conditions anticipated in the beach protection application.

In evaluating the materials, it became clear that additional support was going to be required to withstand even moderate water turbulence forces. Thus, the mat would require at least two separate components, a structural web and a sorbent material firmly affixed to the web. It was reasoned that the cost of manufacturing this structure would be much more easily justified if the mats were reusable.

BEGIN LAST LINE OF TEXT
BOTTOM OF IMAGE AREA; OUTSIDE DIMENSION FOR TABLES AND ILLUSTRATIONS
3/8"

EPA-287 (Cin.)
(4-78)

Table 1. SORBENT MATERIALS EVALUATED

Name	Company	Description	Cost 1,000/sq ft	Conclusion
Conwed Sorbent Blanket	Conwed Corporation	Vegetable fiber reinforced with polypropylene	$ 96.00	Not applicable-Insufficient strength to hold together in turbulance.
Graboil	R.B.H. Cybernetics Ltd.	Fine pore polyurethane foam 1" x 1' x 2'	$473.20	Suitable sorbent-Somewhat thick and not continuous sheet.
Waterwiper	Johns-Manville	55-60 PPI urethane foam 1/2" x 4' x 50'	$750.00	Pore structure too coarse to hold oil in turbulence.
3M Brand Oil Sorbent	3M Company	Polypropylene fiber blanket 3/8" x 3' x 150'	$165.00	Insufficient strength to withstand turbulence-Oil, water, and sand characteristics good.
Oil Mop	Oil Mop Inc.	Rope supported fibers	--	Not suited to beach protection due to sand entrapment
Oil Snare Adsorbent	Parker Systems Inc.	Flat plastic fibers in bundles	$420-$490	Not suited to beach protection due to sand entrapment.
Petro Trap	Best Textile Co.	Fiberglass bags-Sorbent filled, large and small	$10 ea Lg $6.95 ea Sm	Not correct form for covering a large surface area.
Sorbent Sciences SS	Sorbent Sciences Corporation			
Sorbent Quilt	Earth Technology Corporation	Polyurethane foam 1/2" covered with polypropylene on both surfaces, sewn together	$455.10	Looks very well suited to beach protection, but still needs extra support layer.
Urethane Foams	Scott Paper Co. Bernel Foam Products	Ester based foams available in desired fine pore structures. $ .58/bd-ft for 1/2"	$290.00	Will function equal to specialty urethane oil sorbents-Very well suited to beach protection
Microfoam Sheeting	Dupont	Closed cell polypropylene foam 1/16" thick, $ .09/sq yd.	$10.00	Not suited to beach protection due to closed cell structure.

This is especially the case if the support web and sorbent attachment method must withstand substantial forces imposed by turbulent water, as is the case in the beach protection application. Consequently, two additional requirements were added to the completed mat structure:

1. The mat must be re-usable by at least a moderate number of cycles.

2. The mat must be cleanable by squeeze roller techniques.

The simple squeeze roller cleaning process was specified so that the mat could be cleaned on-site with low cost, highly portable equipment and re-used immediately.

LABORATORY TESTING

Laboratory tests were performed to determine which materials met the basic environmental requirements of the beach protection application. Those tests included behavior of the sorbent floating on calm water, behavior of the sorbent in turbulent water (running tap water) observation of oil adsorption of No. 2 and No. 6 oil from a water surface, and retention of the above oils when sorbent containing them was supported mechanically not in direct contact with a water surface.

Few materials displayed favorable performance in all the above categories. The fibrous natural materials failed mechanically in turbulent water. The materials which showed the best characteristics were the urethane foams and the polypropylene fiber structures. The latter also tended to fail structurally due to the turbulence, but to a much smaller degree than the natural fiber materials.

Further testing was performed with the 3-M polypropylene sorbent and various raw urethanes and urethanes marketed as oil sorbents. The testing included oil retention in a turbulent water environment and testing in the presence of wet and/or dry oil contaminated sand.

The results of these tests indicated the following basic factors which, in general, apply to the beach protection task and sorbent material.

Oil, Sand and Water

In tests with oil, sand, and water, wetness of the sand prior to contamination with oil to a large degree prevents the oil from "wetting" (adhering to) the surface of each sand particle. Wet sand contaminated with oil spontaneously separates from most of the oil (even No. 6) when submerged under water. If the sand is dry when contaminated, however, the sand-oil mixture remains intact when submerged and stays on the bottom because its average density is greater than one. Thus, the beach protection mat will perform best if it keeps the sand, which may be exposed to contamination, wet.

BEGIN FIRST LINE OF TEXT HERE
TYPING GUIDE SHEET
CENTER OF PAGE
TOP OF IMAGE AREA
DROPPED HEAD: BEGIN SECTIONS HERE

Structural Composition

For beach protection applications, sorbents with very fine pores function better than open pored structures. Our laboratory experiments have shown that polyurethane foam materials with a pore density lower than 80 pores per inch do not retain oil under conditions of turbulence. This is presumably due to the low capillary pressure that can be achieved with coarse structures. The coarser urethane foams are, however, better suited to open water harvesting of oil spills as they adsorb oil due to capillary induced flow much more quickly, and water rapidly drains out of the foam when it is mechanically supported above the water surface. With pore densities larger than 80 pores per inch, the material will retain water as well as oil when supported out of the water. Oil is retained in moderate turbulence and additional oil will replace water contained in the polyurethane.

Turbulence-Assisted Adsorption

Turbulence-induced flow through a fine pored urethane sorbent greatly accelerates the rate of oil adsorption over that of capillary flow. Thus, the capillary flow limitations imposed by fine pore structures are not limiting factors in beach protection. Sand is naturally excluded from both fine-pored urethane and fibrous polypropylene. Thus, sorbents of this type clean by the mechanical separation of oil from sand as well as by their unique oil and water surface characteristics.

Microfibrous Polypropylene

Polypropylene microfibrous material (3-M Company) has oil adsorption and retention characteristics which are superior to those of polyurethane. Specifically, the surface characteristics of the material are such that it will not wet with water and the effective capillary size is much smaller than that of the fine pore urethanes. In use, it excludes water and absorbs only oil. However, coupled with this are the disadvantages of limited structural integrity and difficulty in cleaning the material using squeeze roller techniques. A small test mat was made with this material, covered with a spun bonded polyoleofin fabric attached to an anchorable support web.

Polypropylene Foam

Polypropylene foam material was also tested but was found unsatisfactory for beach protection because of its closed cell construction. The only action of this material was found to be on the exterior surfaces with substantially no porosity or internal adsorption of either oil or water taking place. It is anticipated, however, that fine structured open cell polypropylene material would be extremely well suited to beach protection use. However, this material was not found to be available from any manufacturers.

Sand Clean-Up With Sorbents

Both the fine pore urethanes and the microfibrous polypropylenes were tested to evaluate their ability to clean-up oil contaminated sand. Both materials

BEGIN LAST LINE OF TEXT HERE
BOTTOM OF IMAGE AREA; OUTSIDE DIMENSION FOR TABLES AND ILLUSTRATIONS
3/8"

PAGE NUMBER
EPA-287 (Cin.) (4-76)

BEGIN FIRST LINE OF TEXT HERE
TYPING GUIDE SHEET
CENTER OF PAGE
TOP OF IMAGE AREA
DROPPED HEAD. BEGIN SECTIONS HERE

were remarkable in their ability to remove oil from sand when in a wet environment. Experiments were performed where dry sand was contaminated with No. 6 oil and allowed to soak in. When water was added, the oil soaked sand remained at the bottom. Rubbing the oiled sand gently with either sorbent effectively cleaned the sand to the point where only slight discoloration was evident. The urethane withstood the mechanical abrasion very well, while polypropylene showed evidence of mechanical shredding.

Oil-Water Stratification in Urethane

The fine pore urethane foams hold water in a sponge-like manner. Oil replaces the water, however, as the urethane foam has greater affinity for oil than for water. When the foam contains both oil and water, gravity tends to separate the two so that the oil "floats" in a layer on top of the water within the urethane foam itself. Thus, water retention by the urethane foam may definitely aid the beach protection process by floating the oil in a stratified layer away from the beach surface side of the beach protection mat.

No tendency for the oil to float out or free of a totally submerged piece of fine pore urethane foam was noted. Thus, water-oil saturated mats, anchored beneath the water level should not release oil into the water. It should be noted, as well, that the specific gravity of water saturated urethane foam is very nearly unity. Thus, the problem of anchoring this material, such that its buoyancy does not float the anchoring system, should be less difficult.

SORBENT SELECTION FOR FEASIBILITY DEMONSTRATION

In conclusion, of the materials obtained for testing, the best performance was obtained from the fine pore urethanes and the microfibrous polypropylenes. Of the urethanes, Graboil, Sorbent Quilt, and Scott Industrial Foam 100 PPI were satisfactory. However, only the Scott Industrial Foam was available in a form convenient for making large beach protection mats. Therefore, this material was selected for feasibility demonstration use. The area of mats made for the feasibility site demonstration is in excess of 100 square meters (1,074 square feet).

Smaller mats were made approximately 1.22 meters by 3 meters (4 feet by 10 feet) to test the Sorbent Quilt and 3M Brand Oil Sorbent materials also.

SUPPORT WEB

The purpose of the support web is to provide the structural strength required by the mat to endure the turbulent forces of water at the beach zone. It is the intermediate structural member between the sorbent and the anchors in the beach surface. Requirements for the support web are strength, environmental compatibility, availability in the appropriate form and ease of fabrication with sorbents and anchoring systems.

The materials were narrowed down to plastic nets commercially available in web form. Basically, two materials were found available in the proper form: polypropylene netting and polyethylene netting. The former was ruled out

BEGIN LAST LINE OF TEXT
BOTTOM OF IMAGE AREA; OUTSIDE DIMENSION FOR TABLES AND ILLUSTRATIONS
3/8"

EPA-287 (Cin.)
(4-76)

because at low temperatures, the material becomes brittle and cracks. Thus, polyethylene was choosen for the structural web. Examination and evaluation of the forms of polyethylene webbing available resulted in the selection of a web constructed of 1.5 mm (60 mil) diameter strands of polyethylene spaced on 6.3 mm (1/4 inch) centers. Two sets of strands run at right angles and are thermally welded at intersection points. Thus, the total as supplied web thickness is on the order of 3 mm thick. The material is available from Dupont under the brand name Vexar TM in webs 1.22 meters (4 ft) wide.

Polyethylene is a thermoplastic which allows the material to be melted and resolidified to alter its shape, make welds, etc. The transition temperature is approximately 135°C. Loops were made out of excess web material and welded onto the edges of the mat. An anchor rope was threaded through the loops, down each edge of the mat. This anchor rope permits the mat to be anchored periodically along its length to the beach surface.

Alternately, periodic staking reinforcements could be welded into the surface of the beach protection mat as a way of anchoring it to the beach surface. It was felt that the rope system of anchoring would allow for more positive anchors with less stress concentrated on any part of the mat.

ANCHORS

Numerous suppliers of anchors and peripheral equipment were examined for the suitability of their products to this task. The anchors selected for field testing are made by Ajax Home Equipment, Inc. and Laconia Malleable Iron Works. The Ajax anchor (Figure 1) is a screw-in anchor about 61 centimeters (24 inches) long. It is unique in that the screw drive portion is relatively small and, therefore, easy to insert. Also, the anchor has three fins at the top which provide considerable lateral support in use. As the principle forces imparted by the beach protection mats on the anchors will be lateral, the structure is well suited to the application.

The Laconia anchor is a cast iron triangle that is driven into the ground with a drive rod. A single cable 1.07 meters long, the anchor cable, is attached to the center of the triangle. A second cable 1.22 meters long is attached to one of the triangular corners of the anchor. It is used to retrieve the anchor from the ground after use.

Both types of anchor were tested in sandy soil to determine their suitability prior to the on-site demonstration. The Ajax anchor was more easily installed and removed than the Laconia, but the Laconia anchor had much greater holding power and appeared to be more adaptable to pebble beach situations. Therefore, the decisions was made to use both types for the on-site demonstration. The Laconia anchor was ordered as noted above with a longer retrieval cable than anchor cable. This allows both to be hooked when used as an anchor and only the retrieval cable to be hooked for removal purposes. In this manner, the retrieval cable is not burried during use. The Ajax anchors were ordered with tie loops welded on the top and with indents allowing the anchor to be screwed further into the ground.

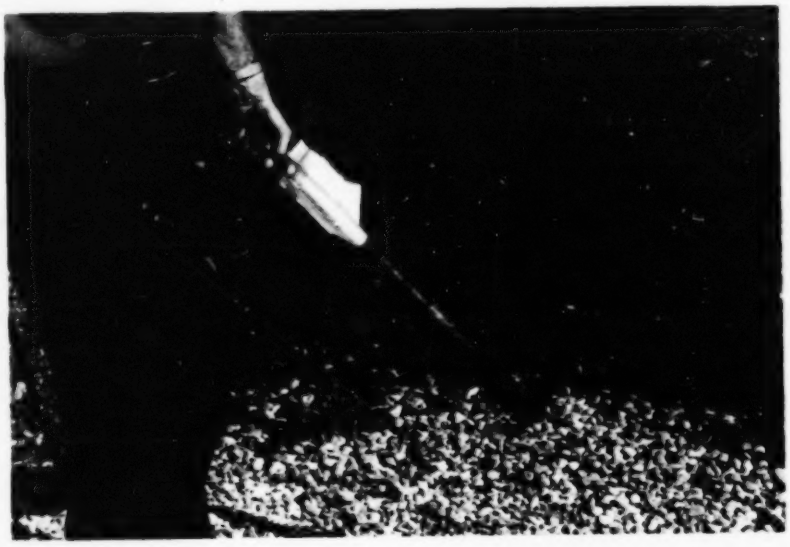


Figure 1. Ajax screw-in anchor.

FABRICATION METHODS

Numerous methods were examined to achieve a suitable method of fabricating the sorbent to the support webbing. A composite made by surrounding the sorbent with the webbing, as in a sandwich structure, was considered, but a mat fabricated in this way might encounter severe problems with the sorbent shifting and bunching between the upper and lower support web. The concept of stitching the sorbent to the support web was also considered. In this case, however, all the force on an area of sorbent would be concentrated along a line of stitching. As good sorbents are very porous and not very strong, this was considered undesirable. Quilting between two webs is one promising approach which tends to remove the above objections, but does require both an upper and lower support web.

The structure selected for implementation is a single, structural web with anchoring reinforcements and sorbent bonded to the web. The web is made from high density polyethylene because of its strength, oil and water tolerance, and temperature compatibility. Fabrication of the anchoring reinforcements is accomplished by thermal welding.

Adhesive Bonding

Due to the size of the demonstration program, and the consequent need for an easy method of fabrication, initial mat fabrication effort was focused on the gluing of the sorbent onto the structural web with adhesives. Several manufacturers had adhesives capable of bonding polyurethane to polyethylene.

Some claimed water and oil resistance as features of their product. However, after obtaining test quantities of adhesives for evaluation purposes, we found no adhesive which would provide moderate bond strength between polyethylene and polyurethane which possessed both oil and water resistance.

An unanticipated complication was encountered in achieving an acceptable demonstration mat for on-site testing due to the absence of suitable adhesives.

Thermal Bonding

Considerable effort was required to develop an alternate bonding method both on a laboratory scale and on a feasibility demonstration scale. A thermal bonding process was, however, developed for bonding the polyethylene support netting to the polyurethane sorbent material. The bond resulting between the materials is primarily mechanical with the polyethylene melting and flowing around the open cell polyurethane structure. Bond strength in properly bonded material is equal to the strength of the polyurethane material. Experiments showed that thermal bonding was unaffected by either water or oil or both.

Thermal bonding, however, required the development of prototype equipment to enable small-sclae fabrication to be undertaken. A platten type heater 0.91 meters by 1.22 meters (3 feet by 4 feet) was designed for this purpose. The temperature of the platten can be varied using an external thermocouple controller from room temperature to over 200°C. A teflon release layer was required between the heater and the molten polyethylene.

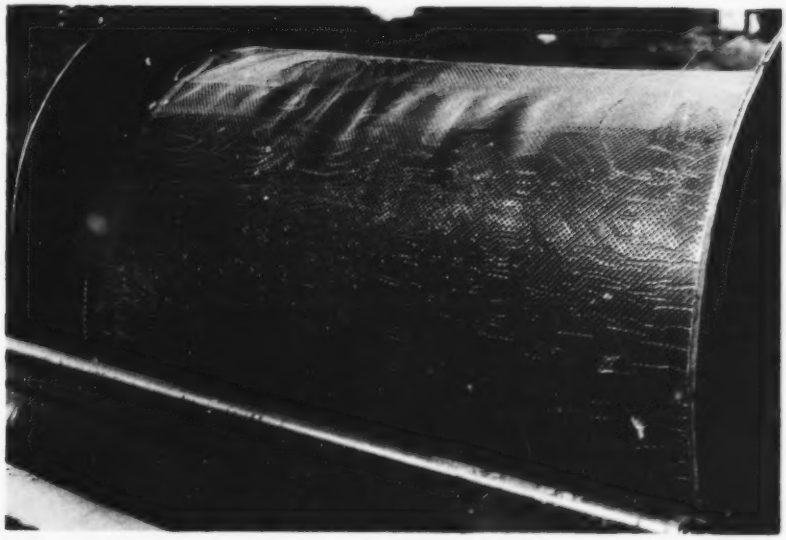
The beach protection mat is made in 1.22 meter wide rolls with 0.91 meters of length being bonded at one time. Preformed anchor reinforcements, which also required special jigging for fabrication, are welded into the support web at the same time that the support web is bonded to the polyurethane. Thus, after the bonding is completed, only the anchor rope need be threaded through the reinforcements before the mat is ready for beach use.

Two men are needed to make the beach protection mats with 0.91 meters being made during each thermal cycle. Thus, the prototype mat constructed in this manner is quite labor intensive.

Figure 2 shows the beach protection mat as fabricated. The polyethylene support web is flattened considerably during the bonding process. This improves the structure from its original form in two ways. The flattened web has a greater percentage surface area in contact with the polyurethane sorbent than does "as delivered" web material. Thus, the web-sorbent bond is much larger and, consequently, stronger. Also, because of the reduced height of the flattened web, the amount of dead volume due to the web structure during the squeeze roller cleaning process is much less. This, in turn, makes the squeeze roller cleaning process much more effective in removing oil and water from the mat.

In conclusion, the thermal fabrication process imparts a number of desirable characteristics to the completed beach protection mat. Its principle disadvantage is the process complexity, jigging and labor required to fabricate mats on a small demonstration scale. It is not anticipated that this disadvantage

BEGIN FIRST LINE OF TYPING GUIDE SHEET
CENTER
TOP OF IMAGE AREA



production level.

Figure 2. Thermally bonded test mat,

MAT IMPROVEMENTS FOR SECOND TEST DEMONSTRATION

The first on-site test demonstration indicated that some improvements were necessary in the anchor loops which attach the sorbent mat and web to the anchor rope. The 30 meter mat used in the first on-site test demonstration, as well as the two 3 meter test mats, were made using anchor loops welded to the edges of the mat supporting web through which the anchor rope passes. Thus, the rope lies straight along the length of the mat, going through loops that are roughly 7 to 10 centimeters long. The problem with this approach is that when anchor hooks are connected to the rope between anchor loop points, the forces placed on the anchor loops are not normal to the length of the mat but have a component along the length of the mat as well. This concentrates all the force at the edge of the anchor loop. Individual strands of the support web material of which the loop is made carry all the force and will break causing the loop itself to rip. Also noted during the first demonstration was the tendency of the exposed edges of the loop to catch in the vehicle entrance slit when the mat was being squeeze rolled cleaned.

The first demonstration mats also did not possess any extra reinforcement along the outside edges of the mat. This is judged to be necessary because at the first demonstration during manual handling of the mat, in somewhat of a rough manner perhaps, the mat tore from the outside edge toward the center. The reason for the ripping was analyzed and it was determined that forces are concentrated at the edge of the anchor loops due to the fact that the anchor rope forces are all transmitted through the anchor loops. Thus, the region around the anchor loops,

BEGIN LAST LINE OF TEXT
BOTTOM OF IMAGE AREA; OUTSIDE DIMENSION FOR TABLES AND ILLUSTRATIONS
3/8"

PAGE NUMBER
EPA-287 (Cln.) (4-76)

especially at the edge of the mat, needs to be stronger than the bulk surface area of the mat itself.

The approach taken in making two additional mats for the second on-site demonstration was to redesign the anchor loops at the edge of the mat. The design was changed from an anchor-loop type of arrangement with a rope passing through it, to a reinforced grommet in thermally welded web material. Tests made using the grommet placed between two layers of web support material revealed the fact that the force concentrations around the grommet were too large and the grommet ripped the material when excessive force was applied. Something on the order of 50 lb of force would rip the grommet out of the web material. Thus, a small region of further reinforcement in the area of the grommet was needed to provide additional strength. This was accomplished by using a 1.6 milimeter thick (1/16 in.) linear polyethylene section between two pieces of black web material with the whole assembly being thermally welded together. The 1.6 mm rectangle of solid material was then melted into the two support web pieces using Teflon as a release material. The grommet was then inserted into the three layer reinforced section with the forces of the anchor rope being transmitted to the two layers (Vexar) which were, in turn, welded to the web support material (Vexar) when it was fabricated. This new grommet type anchor loop fabrication permits forces to be transmitted to the mat, both normal to its length and at angles exceeding 45^{0} to the normal without concentrating the stress in any narrow section along the anchor point to supporting web boundary. Thus, significantly increased strength is obtained with the anchor point construction. Additionally, after fabricating the mat, the anchor point support loops are cut so as to taper them into the web in regions where no stress is incurred in the anchor attachment webbing. This permits significantly smoother operations of the squeeze rollers in the vehicle as the taper gently guides the mat into the squeeze rollers rather than catching them in the entrance slot of the vehicle. Figure 3 shows the design of the grommet type anchor point. Figure 4 is a photograph of a grommetted anchor loop beach protection mat on the beach protection vehicle.

The final structural difference between the first demonstration mat and the second two demonstration mats is that the second mats were constructed with an extra reinforcing strip of polyethylene web material approximately 2 cm wide on the edges of the width of the mat. Thus, the strips are the full 30 m long by 2 cm wide and are thermally bonded into the mat yielding a double strength region at the edge of the mat for additional tensile strength.

Sealed Sorbent

Two mats were made for the second test demonstration. One was fabricated using 100 pore per inch polyurethane foam and polyethylene support webbing with the new grommet anchor points as presented in the previous section and was otherwise exactly the same as the mat used in the first test demonstrtion. The second mat had, in addition to the new anchoring and reinforcing technique, a layer of 4-mil-thick polyethylene sheeting which was thermally bonded during the fabricating process between the polyurethane foam and the polyethylene support web. This produces a solid layer of polyethylene on the bottom surface of the mat which effectively seals polyurethane foam on that surface. Thus, during use,

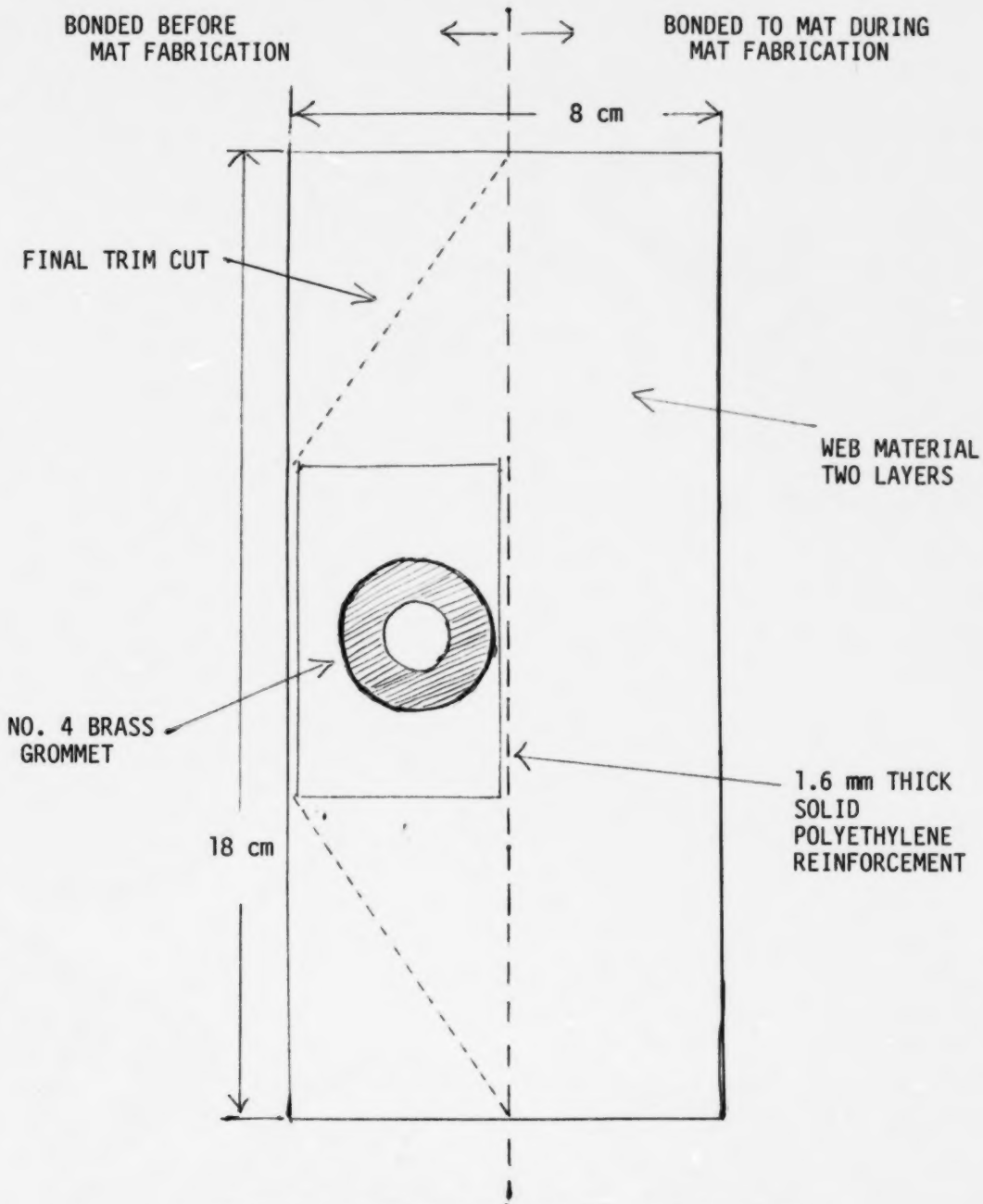


Figure 3. GROMMET TYPE ANCHOR POINT DESIGN

BEGIN FIRST LINE OF TEXT HERE
TYPING GUIDE SHEET
CENTER OF PAGE
TOP OF IMAGE AREA
DROPPED HEAD; BEGIN SECTIONS HERE

the top surface of the mat is porous and allows circulation of oil and water in the urethane. However, the bottom surface is sealed, thus preventing leaching of the mat's contents onto the beach. It was reasoned that this type of mat would be preferable in situations where the oil contained in the mat might possibly drain through the mat onto the beach. The sealed bottom mat might prove superior in situations where very light oils were present or where the mat is left on the beach after absorbing oil for extended periods before it can be cleaned.

Testing the two types of mats, open bottom and sealed bottom, in actual oil spill situations will be required to determine which has the best beach protection performance under various spill conditions.

Figure 4. Unsealed, grommetted mat on beach protection vehicle.

BEGIN LAST LINE OF TEXT
3/8"
BOTTOM OF IMAGE AREA; OUTSIDE DIMENSION FOR TABLES AND ILLUSTRATIONS

EPA-287 (Cin.)
(4-76)

BEGIN FIRST LINE OF TEXT HERE
TYPING GUIDE SHEET
CENTER OF PAGE
TOP OF IMAGE AREA
DROPPED HEAD; BEGIN SECTIONS HERE

V. BEACH PROTECTION VEHICLE REQUIREMENTS

APPROACH

The work undertaken in this research effort is to demonstrate the feasibility of protecting beaches from damage due to oil spill incidents using beach protection mats anchored to the surfaces of a beach and a modified all terrain vehicle(ATV)to aid in transporting, laying down, cleaning and picking up the mats. The size scale of the vehicle, in the present effort, is much smaller than those previously developed for restoration of contaminated beach sand.[14, 15] With the small size comes anticipated advantages of easy transportability, ease of handling, much lower anticipated cost per unit, and economy of operation, especially on smaller spills. The low cost per unit should allow more vehicles to be built and stored ready for operation in areas likely to be exposed to damage from oil spills. Thus, the reduced time to deployment of a large number of vehicles and ease of transport make the beach protection system capable of responding rapidly to an oil spill incident. The primary aim of the system is to prevent damage from occurring at the beach surface rather than to clean up damage after it has occurred.

The beach protection vehicle was developed by modifying a commercial ATV which was designed primarily for recreational use. The commercial vehicle has two-cycle, two-cylinder engine capable of a maximum power output of 26 horsepower and a maximum speed on the order of 40 miles per hour. It has a steel channel frame, a plastic molded body, and six ultra low pressure ballon tires. The tires provide large area low pressure contact with the ground which prevents the vehicle from bogging down in sand, mud, or even heavy snow. The three tires on each side of the vehicle are directly driven by two separate drive trains--one for the right side and one for the left. Maneuvering the vehicle is accomplished in the same manner as is used with tracked vehicles. Forward motion is achieved by driving both left and right drives in the forward direction. A right turn is accomplished with forward drive applied to the left drive (set of wheels) and braking force to the right drive. Drive and braking forces are applied to each set of wheels by two levers which actuate transmission bands. One lever controls the left drive and the other controls the right. The un-modified vehicle weights approximately 600 lbs. (273 kg).

The ATV described above was judged an excellent starting point for developing a vehicle which had modifications designed to fulfill the unique needs of the beach protection task, the price (approximately $2,000), size, and maneuverability make it very attractive for this use.

The approach used was to start with the commercially available vehicle, develop specifications for beach protection use and subcontract the modifications to a firm that had previous experience in modifying ATVs for special purposes.

BEGIN LAST LINE OF TEXT
BOTTOM OF IMAGE AREA; OUTSIDE DIMENSION FOR TABLES AND ILLUSTRATIONS
3/8"

EPA-287 (Cin.)
(4-76)

BEGIN FIRST LINE OF TEXT HERE
TYPING GUIDE SHEET
CENTER OF PAGE
TOP OF IMAGE AREA
DROPPED HEAD: BEGIN SECTIONS HERE

The specifications were developed in conjunction with the subcontractor and progress was monitored as the modifications were made. As the vehicle modifications were of an experimental R and D nautre, detailed drawings were not developed to specify all parts used in producing the beach protection vehicle. Rather, photographs were taken as vehicle modifications progressed to record the layout and function of various components.

Production of a prototype vehicle to be used as a model for a mass produced beach protection vehicle would require a much more costly investment of time and money than was possible as part of the present program. Each component would require through design evaluation, life-testing, cost analysis, supply evaluation and so forth to evaluate its suitability for this application. In addition, the completed model vehicle would need to be subjected to life tests and operational stress testing before a final design could be accepted as a prototype production model.

VEHICLE DESIGN OBJECTIVES

The modifications to the commercial all terrain vehicle were specified to meet the following design objectives:

(a) The ATV will be modified to layout, squeeze roller clean, and wind-up beach protection mats with a 4 ft. (1.22 meter) wide adsorption surface plus at least 2 inches (5.08 cm) on each side for anchor rope allowance.

(b) Both squeeze rollers and take-up roll shall be powered from vehicle power.

(c) Oil and water squeezed out of the beach protection mat shall flow into a tank appropriately incorporated into the ATV.

(d) Means shall be provided to prevent excess forces on and damage to the mat by the vehicle due to misalignment, foreign objects, variable feeding conditions, etc.

(e) The modifications will permit easy mounting and unmounting of cleaned mats on the ATV by incorporating reuseable spools in the design. A minimum of three empty spools are to be supplied, each to hold 100 ft. (30.5 meters) of beach protection mat (1/2 inch, 1.27 cm thick).

In addition to the above specific objectives, the vehicle was also required to operate in a transport mode such that it can be driven to and from a beach site and transport at least one roll of beach protection mat. No constraints were placed on the speed of the various vehicle processes as it was felt that these would become evident with experimental testing as the vehicle modifications progressed.

BEGIN LAST LINE OF TEXT
BOTTOM OF IMAGE AREA; OUTSIDE DIMENSION FOR TABLES AND ILLUSTRATIONS
3/8"

PAGE NUMBER
EPA-287 (Cin.)
(4-76)

VEHICLE MODIFICATIONS

The degree of vehicle modification needed to meet the design objectives for beach protection use was extensive. The only items of the original ATV that were not modified were the channel frame and six wheel drive train system.

The primary vehicle modifications performed before the first on-site test were as follows:

1. Remove the original body top to permit complete alteration of the top surface of the vehicle.

2. Remove the original fuel tank and relocate a new fuel tank in the rear of the vehicle. This allowed use of space in the front of the vehicle for oil-water squeeze roller output storage.

3. Driver controls (shift lever,transmission band levers, throttle and ignition switch) relocated in rear of vehicle to permit operation from rear platform.

4. Original variable ratio drive system between engine and transmission removal and replaced with constant ratio drive to permit controlled constant speed operation.

5. operation by driver standing on platform.

6. Tank built inside front portion of vehicle (formerly driver's position) for oil-water storage. Valve drain installed through side of vehicle at bottom of tank.

7. Platform containing drip pan,squeeze rollers, take-up reel, and mechanical drive for squeeze rollers and take-up reel built over storage tank.

8. Move engine and redesign engine to transmission power coupling to permit operation of vehicle at slow controlled speeds.

9. Design power take-off and clutch arrangement between transmission input shaft and squeeze roller, take-up reel drive.

10. Design take-up reel with replaceable cores for holding beach protection mats.

11. Dual chain driven squeeze roller system designed with variable squeeze spacing. Tension springs are used to provide roller compression.

12. Vehicle tests with 30 meter (100 ft) mat were performed to evaluate suitability of vehicle modifications and make adjustments where required.

The vehicle was used with the one 30 meter test mat and two 3 meter test mats at the first on-site test demonstration of April 30,1975 to May 1, 1975. Performance of the vehicle during the first test demonstration is presented in Chapter VI of this report. As with any initial field test, a number of items which needed improvement were noted. Thus, upgrading modifications were performed between the first and second demonstrations. Among these were the following:

1. Correct problems of a slipping engine drive belt by converting from a V-belt drive to a positive drive (toothed) belt between engine and transmission . Reduce engine to transmission speed reduction ratio.

2. Re-design the gearing ratios to increase the rotational speed of and lower the torque on transmission components. This required new jackshafts between the transmission and axle drives and new components in the squeeze roller take-up system.

3. Repair a broken left transmission shifting dog and separate the left and right power train shift actuators to prevent recurrance of the problem.

4. Re-design throttle system to compensate for the observed loading characteristics of the two-cycle engine. The new system has a friction locked throttle plus a spring returned trigger operated throttle. Thus, extra power can be applied for maneuvering and climbing up grades without danger of destroying the engine when removing the load.

5. Additional holes were cut in the drip pan at the edges of the holding tank to minimize spill over.

6. A hand wheel was added to the squeeze roller drive to permit easier and safer hand threading of beach protection mats into vehicle rollers.

7. Added a rubbing block to squeeze roller chain drive to prevent chain from jumping off small sprocket.

8. Safety shields were added to both sides of the beach protection vehicle to cover the chain drive and to prevent accidental access to squeeze rollers.

9. Incorporate positive detents into the squeeze roller drive clutch to prevent slippage in the clutch.

10. Purchase and incorporate anchor points for plastic containers to be used to transport anchors, ropes, and tools needed for beach protection.

11. Remove burs from take-up reel bolt ends.

12. Trim corners of entrance slot pieces to prevent anchor hooks from catching.

13. Remove fuel from tank and refill using high test unleaded gasoline with synthetic base two-cycle engine oil. This should reduce smoke caused by unburned oil and reduce oil fouling of spark plugs.

In addition to the modifications listed above, numerous smaller tasks, such as lubrication, adjustment of spring tensions, and other maintenance operations, were also performed. Figures 5 shows the vehicle prior to the second on-site test.

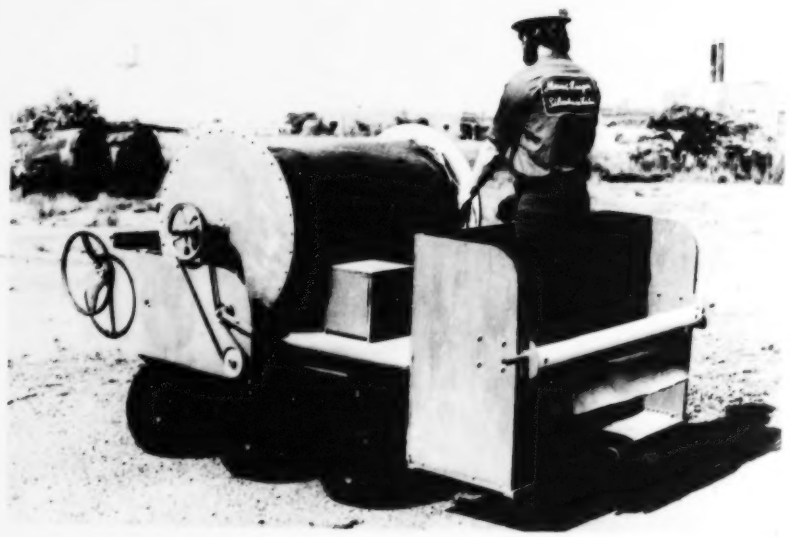


Figure 5. Beach protection vehicle before second onsite test.

OPERATION AND MAINTENANCE

Vehicle operation controls all accessable from the drivers platform at the rear of the vehicle are as follows:

1. Ignition starter switch.
2. Choke
3. Two drive control levers.

4. A spring returned trigger throttle located on right drive control lever.

5. Two separate transmission shifting levers located in front of and below the drive control levers.

6. The top lever of the two levers to the left of the driver (black) is the squeeze roller and take up reel clutch. To the right is "ON" to the left "OFF".

7. The bottom lever (red) is a fixed position engine throttle. Left is slow, right is fast.

8. A fuel shut-off valve is located near the fuel tank. Up is "ON".

Operation of most vehicle controls is self-explanatory. The drive control levers control the right and left drive trains, respectively. The two drive trains are completely independent. Forward motion of the vehicle is obtained by shifting both transmission levers into forward gear (handles pointing toward driver) and pushing drive levers forward. Pulling a drive lever back when the transmission is forward applies a braking force to the drive train. Reverse motion is accomplished by shifting both transmission levers into reverse (handles pointing away from driver) and pulling back on the drive control levers. In reverse, forward pressure applies the brakes. The transmission has a neutral position (handles pointing toward each other),however, there are no brakes available when the transmission is in neutral. Thus, care should be taken to keep one drive train in gear at all times when shifting on a grade.

The spring returned throttle control is used in the same manner as a car's gas pedal to apply additional power as needed. As with any throttle controlled engine, care must be exercised to prevent engine damage due to excessive engine speed. The fixed position throttle should never be adjusted to cause excessive speed when the engine is unloaded.

Squeeze Roller Take-Up Reel Operation

Loading and cleaning-- The mat is loaded through the entrance slot in the front of the vehicle manually and the wheel at the left front of the vehicle is turned manually to feed about 1¼ meters (4 feet) of mat through the rollers. The end of the mat is placed beneath the friction pad on the take up roll and the slack is taken up by turning the take up reel. Turn top of reel toward the front of the vehicle.

Machine powered cleaning is accomplished by engaging the squeeze roller clutch at the driver's position and using the drive levers to steer the vehicle forward and maintain a slight amount of slack in the mat as it is picked off the beach surface.

The tank drain valve is located on the left side between the front two drive wheels. It should be closed during squeeze roller operations. Draining the tank of fluid removed from the beach protection mats may be accomplished by connecting a hose to the drain valve or by inserting a suction tube through the large opening at the top of the tank. Operation in the later mode requires the use of a self-priming pump. Whereas in the former mode gravity draining can be

BEGIN FIRST LINE OF TEXT HERE
TYPING GUIDE SHEET
CENTER OF PAGE
TOP OF IMAGE AREA
DROPPED HEAD: BEGIN SECTIONS HERE

used, in most situations it would still be advisable to pump the fluid from the vehicle tank to a temporary storage vessel located at a higher elevation.

Removal and Disassembly--The mat take-up reel can be removed from the vehicle either with or without a beach protection mat wound on the core. To remove the take-up reel, remove the 4L750 drive belt from the left end of the reel. Remove bolt from each hold down wheel bracket found at either end of the take-up reel and swing the bracket out of the way. Lift the take-up reel and rest it on the ground. Removal of the core from the reel is accomplished by loosening the large bolt in the end of the axle. Remove the pin which goes through the end plate bushing and the axle. Both the bolt and the pin are located at the non-driver end of the axle. Once the pin is removed, slide the end plate off the nondriver end of the axle. Remove the core from the axle.

Assembly of the take-up reel and mounting of the assembled take-up reel are accomplished by reversing the above process.

Adjustments--
There are two adjustments provided for in the vehicle modifications. The first is a squeeze roller compression adjustment which is made by tensioning springs which are attached to each of the top squeeze roller brackets. The tensioning is done by adjusting the position of the threaded rods to which the squeeze roller springs are attached. High squeeze roller compression insures effective cleaning. The disadvantage of high squeeze roller compression is primarily that foreign objects may cause more operational difficulties. As both squeeze rollers are driven and they do not rotate relative to each other when separating, little effect on mat life is expected from compression during cleaning.

The second adjustment is take-up drive tension. This is accomplished by adjusting the idler tensioning spring which acts on the take-up reel drive belt. In designing a system of this type, the difficulty arises that the tension on the web varies with the diameter of the roll when a constant torque is applied to the take-up reel. Also, the angular velocity of the take-up reel decreases as the roll size increases. The simplest compromise in an all mechanical drive is to design the take-up reel speed just equal to the squeeze roller speed for small diameters and permit a constant torque slip to develop as the roll gets bigger. Thus, the "V" belt is designed to slip on the take-up reel pulley.

Damage to the vehicle caused by excessive torque in the squeeze roller and take-up reel system is prevented by the drive clutch. Two tapered detents in the clutch driven sprocket will disengage from the driving plate of the clutch mechanism when excessive torque is encountered. A periodic clunk from the engine compartment will indicate an excessive torque condition.

Fuel
The manufacturer of the vehicle's engine recommends that it be operated with a high octane unleaded motor fuel with a 20:1 two-cycle oil mixture. We have found considerable difficulties in operating this engine due to oil fouling of the spark plugs and poor low speed performance. However, by using a synthetic oil (Spectro Gold) according to the manufacturers recommendations, less difficulty with oil fouling was experienced. The high octane rating of the fuel is required by the high compression ratio of the engine.

BEGIN LAST LINE OF TEXT
BOTTOM OF IMAGE AREA, OUTSIDE
ENSION FOR TABLES AND ILLUS-TRATIONS
3/8"

EPA-287 (Cin.) (4-76)

BEGIN FIRST LINE OF TEXT HERE
TYPING GUIDE SHEET
CENTER OF PAGE
TOP OF IMAGE AREA
DROPPED HEAD: BEGIN SECTIONS HERE
6-1/2"
9-1/8"
BEGIN LAST LINE OF TEXT
BOTTOM OF IMAGE AREA, OUTSIDE DIMENSION FOR TABLES AND ILLUSTRATIONS
3/8"
PAGE NUMBER
EPA-287 (Cin.) (4-76)

Lubrication and Maintenance

All chains and bearings should be kept lubricated using heavy oil or grease as appropriate. Chain tensions should be checked periodically and adjusted if excessively loose or tight. The transmission should be kept filled to the upper plug level with automatic transmission fluid.

The fluid tank in the front of the vehicle should be drained after use. If the vehicle was used in salt or brackish water, it should be thoroughly washed off immediately after use and the tank should be flushed out.

The lead acid battery should be maintained at full charge during periods of storage.

BEGIN FIRST LINE OF TEXT HERE
TYPING GUIDE SHEET
CENTER OF PAGE
TOP OF IMAGE AREA
DROPPED HEAD: BEGIN SECTIONS HERE

VI. ON-SITE DEMONSTRATIONS

The prupose of the test demonstrations of the beach protection system is to assess the feasibility of protecting a beach in the event of an oil spill using beach protection mats anchored in the intertidal zone together with a vehicle modified to assist in deploying cleaning,retrieving, and transporting the mats. In the course of the test demonstrations, design features and limitations of mats, anchoring system, deployment techniques and vehicle design become apparent that might go unnoticed in isolated tests of individual components.

The test demonstrations were planned to take place in regions where oil spills are probable occurrences, but were not planned as responses to oil spills as they occured. Thus, the experiences gained relate to the deployment of beach protection mats in the presence of intertidal water turbulence and intertidal beach surfaces, but not in the presence of oil spilled into the water. Thus, the behavior of the beach protection mats in oil-water-sand mixtures was gauged from the literature reports of sorbent material performance and laboratory tests with sand, water, and oil mixtures.

TEST SITE DESCRIPTION

The site of the two on-site tests was initally planned to be Boynton Beach in the Township of Woodbridge, New Jersey. This site is on the Arthur Kill and has sustained considerable enviromental damage from oil spills as well as from other industrial and municipal contaminants. The beach, at the turn of the century, was a popular public beach area, but the level of industrial activity and waste pollution has increased to the extent that the beach has lost it resort nature and only the more viable biological species can survive in the surrounding waters. There is evidence of environmental improvement in the Arthur Kill at that location, however, as local fisherman have recently reported catching scrod in areas where a few years ago none could be found.

The Boynton Beach site has one distinct disadvantage for conducting experimental tests, however. It is located immediately adjacent to a public highway, Cliff Road, which makes access to the site very easy on the one hand, but, on the other hand, makes the problem of security at the test demonstrations unnecessarily complex. Additional personnel would be required to prevent spectators from interferring with tests and tests involving the deployment of mats overnight would require 24 hour security protection.

An alternate site for conducting the test demonstrations is located on the Arthur Kill between the Public Service power plant on the north and the outlet of Smith's Creek on the south. This is located immediately north of the Boynton Beach site which is located just south of the Smith's Creek outlet. This alternate test site is called the Sewaren Beach and is planned for development

BEGIN LAST LINE OF TEXT
BOTTOM OF IMAGE AREA OUTSIDE DIMENSION FOR TABLES AND ILLUSTRATIONS
3/8"

PAGE NUMBER
EPA-287 (Cin.) (4-76)

into a town park by the Township of Woodbridge. The environmental character of the Sewaren Beach is similar to Boynton Beach with the exception that the area was once a natural marshland which has been dyked with sand. The entire area between Smith's Creek and the Arthur Kill is filled with dredging material from the Arthur Kill. The Sewaren Beach therefore possesses a mixture of materials varying from pebble beach consistency to sand to silt and decaying marsh.

The Sewaren Beach site is accessable by land, only by going through the property of the Public Service power station as it is part of a penninsula bounded by the Arthur Kill and Smith's Creek. No road existed on the penninsula to permit easy access to the beach itself before demonstration tests, and access to the Public Service property is controlled by a main entrance gate. Thus, the Sewaren Beach site would eliminate the need for additional security precautions as well as provide an excellent site for testing the beach protection system.

Both the Sewaren Beach site and the Boynton Beach site has approximate latitude and longitude coordinates of $40^{o}32'$ N and $74^{o}16'$W, respectively.

SITE SELECTION

A site visit was made to the proposed test sites in Woodbridge Township, New Jersey on March 6, 1975 for the purpose of selecting the location for conducting the demonstration tests of this program. Both the Boynton Beach and Sewaren Beach sites were examined by representatives of the Township of Woodbridge, Eugene DeStefano; the Environmental Protection Agency, Leo McCarthy, Frank Freestone and Jack Farlow; and RRC International, Inc., Paul Bakeman. The site was selected to be on the Sewaren Beach due first to its suitability and variety of materials present and second to its limited accessibility and reduced requirements for on-site security.

SITE PREPARATION

The site was prepared for the on-site demonstration tests by the Township of Woodbridge under the direction of the Division of Engineering, Department of Public Works. First, permission for access was obtained from the Public Service power plant. The original plan was to cut a temporary opening in the fence which surrounds the power plant at a location a hundred feet or so from the high tide water line on the Arthur Kill. A temporary roadway could then be constructed to permit easy access through the fence. This fence would then have to be repaired following the test demonstrations.

Access to the Sewaren Beach test site was provided instead by scraping a roadway around the Public Service fence. This had the advantage that continuous access could be provided to the Township of Woodbridge after the test demonstrations were complete and other vehicles, such as cars of interested observers, could be driven closer to the test site. In addition to grading the road, an access to the beach from the higher level of the dredge-filled dyke was graded through the dyke to facilitate access to the beach.

Additional beach preparation consisted of manually raking away the debris which accumulates on the beach surface after each tide cycle. The debris of concern

BEGIN FIRST LINE OF TEXT HERE
TYPING GUIDE SHEET
CENTER OF PAGE
TOP OF IMAGE AREA

was primarily floating solid waste material combined with wooden debris from docks, abondoned ships, etc. Unfortunately, each successive tide brings in considerable additional debris such that after a dozen or so tide cycles, it is not possible to tell which areas of beach have been cleaned of debris and which have not.

The last item of site preparation was to survey the beach site for the purpose of gauging the anticipated tide levels. This was done by Woodbridge Township personnel and stakes were placed in the beach to identify the 3 feet (88 cm) above mean low tide level and to mark two 100 foot (30.5 meter) stretches of beach.

OBJECT OF ON-SITE TESTS

The principal object of on-site testing is to gain experience in using the beach protection system and to demonstrate the feasibility of anchoring beach protection mats in the intertidal zone and using a modified ATV to aid in deploying, picking-up, squeeze roller cleaning, and transporting the mats. Two on-site test demonstrations were scheduled as part of the phase one feasibility study. The first was to shake down the system and determine obvious weak points in the system. Are the anchors strong enough? Is the mat of sufficient strength? Does the sorbent separate from the structural support mat during deployment? Are additional anchors needed to secure the mat to the beach surface? Does the vehicle operate properly?

Difficulties identified during the first on-site test can be analyzed and possibly rectified during the period between the first and second on-site test demonstrations. Thus, the second on-site test serves to verify which problems have been solved and which require further effort. The second on-site test also presents the opportunity to demonstrate the feasibility of using the system to protect beaches from oil spill damage both to the public and to persons involved with oil spill clean-up and prevention measures. The interest spawned by a public demonstration of the system should help the beach protection feasibility study develop to the eventual goal of developing a response capability to oil spill emergencies as they occur.

A list of projected tests was developed prior to the first Sewaren test demonstration as a guide to follow during the test. Thus, key items of interest would not be neglected during the test demonstration. The list of projected tests is presented in Table 2. Also needed to coordinate the tests is a reasonable estimate of the tide times and anticipated heights. Table 3 shows the times and heights of anticipated tides at Sandy Hook, New Jersey during the period of the first demonstration. The tide tables list difference values for Rossville ($40^{o}31'$ N, $74^{o}15'$ W) of 17 and 3 minutes later for high water and 25 and 13 minutes later for low tide, respectively. It should also be noted that all times are relative to the 75^{o} W time meridian and are thus Eastern Standard time values. The height corrections for both Rossville and Tottenville are +21 cm (0.7 feet) for high water with no correction for low water.

CONDUCT OF FIRST ON-SITE TEST

The first test site demonstration was conducted on April 30, 1975 and May 1, 1975 at the Sewaren Beach site. The overall test schedule was as follows:

BEGIN LAST LINE OF TEXT
BOTTOM OF IMAGE AREA OUTSIDE DIMENSION FOR TABLES AND ILLUSTRATIONS
3/8"

EPA-287 (Cin.)
(4-76)

BEGIN FIRST LINE OF TEXT HERE
TYPING GUIDE SHEET
CENTER OF PAGE
TOP OF IMAGE AREA
DROPPED HEAD: BEGIN SECTIONS HERE

April 30, 1975 (A.M.)--Deploy both 3 meter (10 feet) test mats at the 91 cm (3 feet) above mean low water level using two Laconia drive point anchors and two Ajax screw-in anchors to secure each mat.

Test insertion and removal of anchors in various areas of beach.

Use vehicle to transport materials to the beach and evaluate performance of vehicle on beach.

April 30, 1975 (P.M.)--Examine and remove two 3 meter (10 feet) test mats.

Test vehicle squeeze roller cleaning system on 3 meter test mats.

Test removal of Laconia drive point anchors using a chain fall and tripod arrangement.

Perform dry run testing on 30 meter (100 feet) thermally bonded urethane mat using vehicle to lay-out, squeeze roller clean and pick-up mat.

Redeploy two 3 meter test mats slightly below 91 cm (3 feet) above mean low water level and leave exposed overnight.

Load and transport vehicle for overnight storage.

Table 2 FIRST SITE DEMONSTRATION PROJECTED TESTS

Task	DESCRIPTION
1	Insert Laconia drive point anchor. Evaluate problems and determine time required.
2	Insert Ajax screw-in anchors. Evaluate problems and determine time required.
3	Remove above anchors. Evaluate removal problems and time.
4	Vehicle testing. (a) Drive vehicle on beach to determine handling, turning characteristics and so forth on the beach surface. (b) Practice following beach contour with vehicle to facilitate precise lay down and pick up of mat. (c) Measure rate of travel of vehicle in moving material to beach.
5	Anchor two small 10 feet test mats below high tide line. Allow tide to cover them and retrieve after tide recedes.

BEGIN LAST LINE OF TEXT
BOTTOM OF IMAGE AREA OUTSIDE DIMENSION FOR TABLES AND ILLUSTRATIONS
3/8"

EPA-287 (Cin.) (4-76)

6	Dry test 100 foot urethane-vexar mat using vehicle above high tide line. (a) Determine time required to lay out 100 foot section. (b) Determine time required to squeeze roller process and wind up dry mat.
7	Use vehicle squeeze rollers to clean the two small mats wet tested in Task 5.
8	Insert 22 anchors for deploying layer 100 foot mat just below the high tide line.
9	Lay out 100 foot mat using vehicle and attach anchor ropes to mat anchor line. Measure rate of lay down.
10	Take beach samples from underneath mat. Allow to remain anchored in place through high tide cycle.
11	Take beach samples from same locations after high tide.
12	Test one small location on mat with oil. Allow to stand one-half hour and then sample beach below oiled region.
13	Remove anchor hooks and use vehicle to squeeze roller clean mat. Determine water content removed from mat and observe any sand entrapment problems. Also measure rate of mat pick up and cleaning.
14	Demonstrate relaying of mat from take up roll position if time permits.
15	If small mats are still usable, anchor one of them loosely just above low tide line. Leave for one cycle and remove.
16	Dry larger mat in open sun or in city garage area if weather is inappropriate.
17	Reroll using manual technique or vehicle and store in polyethylene bag for second demonstration.
18	Return to garage and rinse vehicle, anchors with fresh water to prevent corrosion.

May 1, 1975 (A.M.)--Remove two 3 meter mats from beach. Deploy 30 meter thermally bonded mat at 91 cm (3 feet) above mean low water level using four Laconia drive point anchors and 18 Ajax screw in anchors.

May 1, 1975 (P.M.)--Remove 30 meter thermally bonded mat from anchored position.

Use vehicle to squeeze roller clean and wind-up mat.
Remove all anchors from beach surface.
Pack-up all equipment anchors, ropes, mats, etc., and transport away from beach site using vehicle.
Load vehicle onto trailer and transport away from beach site.

Table 3. TIDE TABLE FOR SANDY HOOK, NEW JERSEY--FIRST SITE TEST

Date	Time (EST)	Tide Height (ft)	Tide level
April 29, 1975	4:15 a.m.	-0.5	low
"	10:16 a.m.	+4.4	high
"	4:23 p.m.	+0.1	low
"	10:37 p.m.	+5.1	high
April 30, 1975	5:01 a.m.	-0.2	low
"	11:09 a.m.	+4.1	high
"	5:11 p.m.	+0.5	low
"	11:27 p.m.	+4.8	high
May 1, 1975	5:51 a.m.	+0.2	low
"	12:02 p.m.	+4.0	high
"	6:07 p.m.	+0.8	low
May 2, 1975	12:17 a.m.	+4.5	high
"	6:45 a.m.	+0.4	low
"	12:52 p.m.	+3.9	high
"	7:08 p.m.	+1.0	low

Due to the inclement weather on May 1, 1975 at the test site and the time at which the large 30 meter mat was retrieved from the beach site, final clean-up and sun drying of the mats was postponed and performed at Latham, New York as was the fresh water cleaning of the beach protection vehicle.

A total of six people were physically involved during the performance of the first on-site demonstration. Three of these had been involved in designing the system and were familiar with its operation. The other three formed a work crew without prior familiarity with the system. They assisted in final preparation of the beach as well as with the insertion and removal of anchors, the handling of mats,

assistance with the vehicle and so forth. A number of visitors and others responsible for assisting in the development of the system acted as observers and provided valuable suggestions and advice.

The Township of Woodbridge was extremely helpful in performing the on-site test as they served as a back-up of resources, including machine shop equipment and personnel, in addition to providing site access, storage of vehicle, surveying of the site, and an on-site work crew.

RESULTS AND OBSERVATIONS FROM FIRST ON-SITE TEST

Anchors and Anchoring System

The Laconia drive point anchors and Ajax screw-in anchors both provided satisfactory anchoring under the conditions experienced during the test. The drive point anchors required two men for insertion; one man held the 1.07 meter (3 ½ feet) long drive rod, while the other drove in the rod with an 8 pound sledge hammer. Insertion time averaged approximately 1 ¼ to 1 ½ minutes for the drive point anchors. The Ajax screw-in anchors only required one man for manual insertion and took from 1 to 1 ½ minutes to insert.

Removal of the drive point anchors was accomplished manually using a 25 lb (11.4 kg) weight as an impulse puller attached to the retrieval cable. Using this method, a great deal of effort was required to remove the anchors. The process took from 1 ½ to 5 minutes depending on the soil condition and the endurance of the man removing the anchor. In contrast, removal of the screwin anchors did not require a high level of effort and could be accomplished in a period of approximately 20 second.

Subjective pulling tests on the anchor cable of the Laconia anchors or on the anchor loop of the Ajax anchors showed little difference in the holding power of the anchors.

With the aid of a chain fall mounted on a tripod, the actual removal time of the Laconia anchors was reduced to approximately 20 seconds. However, this requires an additional piece of equipment to be brought to the beach as well as additional set up time over each anchor. Thus, insertion and removal effort would favor the use of the screw-in anchors over the drive point anchors, at least at beaches with surfaces similar to the Sewaren beach surface.

Two other observations were made relative to the anchors tested. First, both appeared to develop increased holding power as the action of the tidal water packed the beach surface disturbed by anchor insertion. Second, both anchors are subject to corrosion due to salt water, as the drive point anchors are cast iron and the screw-in anchors are fabricated from plated steel tubing and sheet. The screw-in anchors showed greatest deterioration due to corrosion as the plated surface wore off where the highest level of abrasion occurred. In these areas, rusting due to a salt residue was fairly rapid. The drive point anchors corroded only on the cast iron point. The steel anchor and retrieval cables did not corrode.

The ropes and hooks used to attach the beach protection mats to the anchors

performed as anticipated. The individual anchor ropes were 3/8" diameter polypropylene 4.5 meters (15 feet) long. For the large mat, anchors and ropes were spaced at 3 meter (10 feet) intervals along each edge of the mat. The small mats were simply anchored with one anchor off each corner. The only difficulty experienced with the anchoring system was in tying knots and adjusting rope lengths using the polypropylene rope. The rope itself is quite slippery and tautline hitches or boline knots will not remain tied under conditions of tugging. It was found necessary, therefore, to tie a simple overhand knot with a loop attached to the anchor hooks to insure that the rope would not become untied in operation. The disadvantage of using overhand knots is that they become very difficult to untie after being tightened by applying a load.

A solution to the rope length adjustment problem will be needed to facilitate deployment of large amounts of mat in future operational beach protection systems. A stainless steel adjustable rope clamp which is compatible with synthetic ropes might be a suitable solution for all anticipated environmental conditions.

Beach Protection Mat Response

Three mats were tested during the first on-site demonstration. Two were 1.22 meters (4 feet) wide by 3 meters (10 feet) long and one was 1.22 meters wide by 30 meters (100 feet) long. All mats were constructed as part of this program. The mats were constructed as follows:

1. Polypropylene Fiber Sorbent - This 3 meter long mat was constructed using 3 M Company's type 156 Sorbent which was quilted between Dupont's spunbond polyester, Reemay type 2008. The quilt was then stitched to Dupont's Vexar backing to provide the structural integrity needed in the beach environment. Twelve anchor loops of Vexar were thermally welded to the support Vexar to permit attachment of anchor ropes.

2. Commercial Urethane Sorbent - This 3 meter long mat was constructed using Sorbent Quilts from Earth Technology Corp. stitched to a Vexar backing with twelve anchor loops as above. The Sorbent Quilts consist of polyurethane foam stitched between two layers of spunbonded material.

3. Thermally Bonded Urethane - This 30 meter (100 feet) long mat was made using Dupont's Vexar as a support matrix for reticulated, fine pore, ester base polyurethane foam sorbent. The Vexar was thermally bonded into the polyurethane foam to form a single uniformly bonded structure. Anchor loops were bonded to the mat t 61 cm (2 feet) intervals along each side of the mat.

All three mats had sufficient strength to remain intact against the wave action present in the Arthur Kill during the test. The conditions were calm with approximately one-foot waves occurring periodically due to passing ships. The only damage sustained by the mats was a rip which started in the 30 meter thermally bonded mat immediately adjacent to an anchor loop reinforcement. This rip occurred when the mat was manually tugged out of the water by pulling on the anchor loop. As the mat was saturated with water at the time, considerable force was required to initiate the rip.

The anchor loop structure has been carefully examined since the demonstration and the cause of the failure has been attributed to stress concentration at the edge of the anchor loop reinforcement. Stress concentration does not occur with forces applied to the anchor loop perpendicular to the long dimension of the mat, but tangential forces applied by the anchor loop to the mat result in stress concentration and ripping of the mat. Both the stress concentration by the anchor loop design and the rip propagation in the Vexar support structure were examined in detail after the first test demonstration. Changes in anchor point fabrication and inclusion of rip stopping reinforcements are recommended to improve mat design.

Behavior of the mats in the intertidal zone was as anticipated. The polypropylene fiber mat remained hydrophobic throughout each tide cycle and therefore was highly bouyant. It remained on top of the water and conformed to the shape of the wave tops. Both the commercial urethane sorbent 3 meter mat and the 30 meter thermally bonded mat saturate with water during use. They retain a slight positive bouyancy and thus, if anchored loosely, float and conform to the tops of the waves. If the anchor ropes are installed with the preloaded tension, the mats are held underwater as the tide rises.

Initially, there was some question as to whether the mats should be allowed to float during use or whether they should be firmly anchored to the beach surfaces, which during high tide will be underwater. However, it is concluded from observing the action of the water around the mats that a floating mat would afford protection to the beach inland of its location by multiple filtering the water in the vicinity of the shoreline. As the oil will be surface borne, the maximum removal effect will be experienced at the water's surface.

It was also noted during the test demonstration that the force on the mats was greater during the receeding portion of a wave than during the incoming portion of the wave cycle.

Deployment and Recovery Time Factors

The time required to deploy the small 3 meter mats was approximately 15 minutes each using two people. This includes installation of four anchors, attaching anchor ropes between the anchors and the mat using metal hooks and adjusting the length of the anchor ropes to achieve proper tension. These are, however, only test mats and therefore the time required to deploy full size 30 meter mats is much more important.

The 30 meter thermally bonded mat was deployed using the vehicle on the morning of

May 1, 1975. The total time taken to deploy the mat and anchor it to four drive point anchors and eighteen screw-in anchors was 50 minutes. Four men participated in the deployment of the mat; two from the contractor and two from the Woodbridge D.P.W. It was noted that about 20 minutes of this period was spent attaching anchor hooks to the adjustable end of the anchor ropes and adjusting the lengths of each of the 22 anchor ropes. Thus, 20 minutes could be saved by using anchor ropes adjusted to a predetermined length and using a taut line to position anchors on the beach. Also, as all workers gain familiarity with the system, the number of people could be cut from four to three without a slowing down of the installation.

As deployment is not vehicle limited, two teams of workers could work with one vehicle transporting and laying out mats and deploy manually anchored mats at a rate of 120 meters per hour (400 feet per hour).

After the tide has receded and the anchor ropes are removed, the anchors are removed from the beach surface and the mat is squeeze roller cleaned and wound up. At the test demonstration this process was performed in the rain and took longer than anticipated due to slippage in the squeeze roller drive clutch. However, the removal time for the anchors and ropes was less than the time required for installation. The squeeze roller cleaning process required approximately 5 minutes to perform even with the vehicle problems encountered. The designed squeeze roller cleaning process required approximately 5 minutes to perform even with the vehicle problems encountered. The designed squeeze roller speed is 12 meters per minute (40 feet per minute). At this speed, the quantity of oil-water mixture removed from the mat is more limiting than pick-up speed, as all liquids must be transferred from the vehicle's 40 gallon tank to a temporary storage vessel. The mat has a saturated capacity of 472 liters (125 gallons). The mat does not remain saturated with water as the tide recedes and the mat rests on the beach above the water line. The small pore size of the urethane foam of the mat aids in retaining the oil as the water drains away. Thus, the mat is typically not saturated when picked up. During the on-site demonstration, approximately 57 liters (15 gallons) of water was collected in the vehicle tank. An undetermined additional amount splashed over the edges of the drip pan due to the low height of the drip pan edge relative to the tank entrance. Although actual water content of the mat picked up was not determined, it, in general, will vary depending upon tide level, etc., at time of pick up.

Vehicle Operation

The operation of the vehicle at the first test demonstration showed a number of deficiencies that had not appeared in dry land tests. However, the problems experienced were identified and most will be recitified between the first and second test demonstrations.

The rate of travel of the modified all-terrain vehicle in transporting materials, supplies, and driving to and from the beach was measured at approximately 3-½ miles per hour. This speed corresponds to the maximum recommended rotation rate of the engine. The top speed of the vehicle was reduced in making the modifications so that a controlled slow rate of travel would be available for squeeze roller cleaning and mat layout operations.

Observations noted regarding vehicle operation in the traveling mode were:

1. When under heavy load, the engine-to-transmission drive belt slipped.

2. The fixed throttle position provided by the controls was difficult to use with the varying engine loads found in turning, going up hill, etc.

3. The Borg-Warner transmission failed late in the day of May 1, 1975.

4. Considerable care was felt necessary and was exercized in driving the vehicle on the Sewaren Beach to prevent tire punctures from nails in driftwood and broken glass.

The first three difficulties were remedied between the first and second test demonstrations. A positive drive belt system now replaces the "V" belt drive between engine and transmission. A fixed throttle with spring return over-ride replaces the old fixed position throttle. The cause of the transmission failure has been identified and was found to be an inherent difficulty in the original shift linkage design. The transmission itself has been repaired.

The speed of the squeeze roller cleaning mat pick-up operation was performed at the design speed of ½ mile per hour (0.224 meters per second). Thus, the total time required to pick-up and clean the 30 meter mat should be 2¼ minutes. However, slippage was evident in the squeeze roller drive clutch and the field test time was more on the order of five minutes. Even at this speed, however, the mat cleaning process is more rapid than anchor removal and would not be the limiting time factor in recovering deployed mats.

The operation of squeeze roller cleaning the 30 meter mat and immediately re-deploying the mat in its previous location was not performed during the first on-site test. A time estimate for performing this operation can be estimated from the tests performed, however.

Remove 22 Anchor Hooks	2 minutes
Squeeze Roller Clean	5 minutes
Re-lay Sorbent Mat	1 minutes
Attach 22 Anchor Hooks	2 minutes
Total Estimated Time	10 minutes

Thus, a team of three men could conceivable clean and re-deploy 900 feet of mat during the period of 45 minutes before low water to 45 minutes after low water. This assumes that no time is lost in the operation of transferring liquids from the vehicle's 40 gallon tank to a larger storage vessel.

The time required to lay out a 30 meter roll of beach protection mat is approximately one minute. A deployment speed of over one mile per hour can be used

with safety. A quick loading bar is provided with the vehicle such that a second roll can be loaded for deployment in about 30 seconds.

The time required to unload a squeeze roller cleaned roll of sorbent mat and reload an empty pick-up roller on the vehicle is approximately five minutes. This operation requires removal of the loaded take up roll from the vehicle and disassembly of the take up roll. A new core is used in assembling the roll and the assembled roll is installed on the vehicle.

SECOND ON-SITE TEST

The second on-site test was performed during the period from August 12, 1975 through August 14, 1975. The aim of the test was two-fold. First, additional experience was needed with the beach protection system to evaluate the performance of each component and the effect of additions and improvements made after the first on-site test. Second, the system needed to be demonstrated to others involved in or affected by oil spill clean up technology. This latter point is extremely important as improvements in technology are valuable only when they are applied to solve existing problems. Thus, representatives of governmental agencies, private contract clean-up operators and equipment manufacturers and large oil companies were invited to attend a demonstration on the morning of August 13, 1975. The press was also invited to attend.

As mentioned in earlier chapters of this report, numerous system advances had been pursued since completion of the first on-site demonstration. A new method of anchor point attachment was developed. Two new 30 meter beach protection mats were hand fabricated. One of the new mats incorporated a new polyethylene seal on the bottom surface of the polyurethane sorbent. Extensive modification of the vehicle power train design was performed; operational and safety improvements were also incorporated in the vehicle. Lever and winch devices were designed, built, and evaluated to facilitate the task of removing drive point anchors.

CONDUCT OF SECOND ON-SITE TEST

The second on-site test was performed by RRC personnel Albert Armstrong, Paul Bakeman, and John Baackes. Paul Stimson of Independent Associates, the vehicle modification subcontractor, was also present to aid in the event that difficulties were experienced with the vehicle. The Township of Woodbridge scraped the access to the beach site and raked the beach prior to the test. The Environmental Protection Agency supplied two individuals to physically assist with the testing. Table 4 shows the tides corrected to Eastern Daylight time at Rossville from Coast Guard tide data. The second on-site test and demonstration proceeded according to the following schedule:

August 12, 1975 (a.m.)

1. Deploy the 30 meter sealed back mat (from vehicle take-up reel) diagonal to the water line with six anchors (five screw-in anchors and one drive point anchor) to evaluate the mat behavior and review the procedure for the August 13, 1975 demonstration. Six or seven meters of the mat were in the water.

TABLE 4. TIDE TABLE FOR SANDY HOOK, NEW JERSEY--
SECOND SITE TEST

Date	Time (EDT)*	Tide height (ft)*	Tide level
August 12, 1975	12:15 a.m.	+5.9	high
"	6:51 a.m.	-0.4	low
"	12:54 p.m.	+6.3	high
"	7:08 p.m.	0	low
August 13, 1975	1:11 a.m.	+5.5	high
"	7:35 a.m.	-0.1	low
"	1:48 p.m.	+6.1	high
"	8:19 p.m.	+0.3	low
August 14, 1975	2:09 a.m.	+5.1	high
"	8:36 a.m.	+0.2	low
"	2:46 p.m.	+5.9	high
"	9:27 p.m.	+0.4	low

* Corrected to Rossville and Eastern Daylight Time.

2. Squeeze roller clean and wind-up the mat deployed in item 1 above. Remove screw-in anchors.

3. Test 2.4 meter (8 foot) anchor pulling lever for removing drive point anchor from beach.

4. Deploy the two 30 meter non-sealed back beach protection mats, one grommet type and one anchor loop type, below the high tide line. Use 14 anchors to anchor the mats to the beach surface. Use double hooks to clip the ropes along the adjoining edges of the mats together.

5. Remove sealed back mat from the vehicle take-up reel and install an empty core on the take-up reel.

August 12, 1975 (p.m.)

6. After high tide receeded from the tandom deployed mats, the grommet type mat was squeeze roller cleaned and picked up.

BEGIN FIRST LINE OF TEXT HERE
TYPING GUIDE SHEET
CENTER OF PAGE
TOP OF IMAGE AREA
DROPPED HEAD; BEGIN SECTIONS HERE

7. The anchor loop type mat was left deployed and re-anchored to the beach surface.

8. Return vehicle with unsealed grommet type mat to Woodbridge Township garage for overnight storage.

9. Repair damage that had occured to grommetted unsealed mat by thermal welding at the town garage. Rewind on vehicle take-up reel.

August 13, 1975 (a.m.)

10. Transport vehicle to test site.

11. Remove unsealed grommetted mat from take-up reel and install an empty core.

12. As part of public demonstration, deploy sealed grommetted mat from rear platform of vehicle. Anchor as on August 12, 1975

13. Squeeze roller clean and wind-up the sealed grommetted mat deployed above. Remove all anchors.

14. Leave anchor loop mat deployed until August 14 low tide.

15. Return vehicle to storage garage.

16. Presented beach protection system Phase I results and Phase II proposal at Woodbridge municipal building to interested parties.

August 14, 1975 (a.m.)

17. Transport vehicle to beach. Demonstrate its operation to API representatives who were present to inspect the beach site.

18. Pick-up anchor loop type mat at low tide using vehicle and squeeze roller clean.

19. Remove all beach protection materials and equipment from test site.

20. Deliver beach protection vehicle and sorbent supplies to the Environmental Protection Agency Edison, N.J.

BEGIN LAST LINE OF TEXT
BOTTOM OF IMAGE AREA OUTSIDE DIMENSION FOR TABLES AND ILLUSTRATIONS
3/8"

PAGE NUMBER
EPA-287 (Cin.)
(4-76)

21. Visit OHMSETT test site and Sandy Hook beach for the purpose of evaluating them for use in Phase II testing of beach protection system.

The public demonstration of the beach protection system given on the morning of August 13, 1975 generated considerable interest on the part of those present. A number of suggestions and helpful comments were made by the visitors.

OBSERVATIONS FROM SECOND ONSITE TEST

Beach Protection Mat Performance

Three 30 meter beach protection mats were tested in the second on-site test. All were made with fine pore polyurethane foam thermally bonded to a polyethylene mesh support web. One mat which was used in the first on-site test had polyethylene anchor loops and an open back. The other two mats had brass grommets placed in reinforced anchor points connections welded along their sides. One of the new mats had an open back identical to the anchor loop mat; the other mat had a layer of polyethylene sheeting bonded between the support web and the polyurethane which effectively sealed the support web surface.

The anchor loop mat withstood its two day deployment through four complete tide cycles without significant deterioration. The only difficulty noted was slight tearing of some anchor loops due to stress concentrations and catching on the vehicle during squeeze roller cleaning.

The grommet type mats were superior in anchor point durability with no damage to the anchor point structures being experienced during the test. Also the machine cleaning of the mats proceeded more smoothly with the grommetted mats than with the anchor loop mat.

One of the grommetted mats, the open backed mat, ripped in several places adjacent to the grommetted anchor points during the tandem mat test. It was structurally identical to the sealed back mat with the exception that a different flexible brand of 3/8 inch rope was used in the latter mat. No problems were encountered with the mat with the more flexible rope. Analysis of the situation revealed that the stiff rope had taken a set and would not pull through the grommet holes in the anchor points. Thus, the rope, instead of relieving stress on the beach protection mat, was concentrating it on the mat adjacent to some of the anchor points. Part of the difficulty is due to the fact that the rope must make a sharp "S" bend in order to pass through each grommet. If, however, the rope is sufficiently flexible, this does not prevent the rope from sliding through the grommet holes. Thus, an area where further improvement is desired is mat strength. The mats developed in the current Phase I effort demonstrate the feasibility of using beach protection mats to prevent oil spill damage to a threatened beach. However, further effort should be applied to develop reinforced mats capable of withstanding greater turbulent forces. As these are developed, the system will be well suited to a greater variety of oil and hazardous material spill situations.

Anchors and Accessories

The screw-in and drive point anchors used in the first on-site test were re-used in the second test. Both provided anchoring capabilities well in excess of the forces encountered during the tests.

It was noted that the screw in anchors tended to corrode and that the lateral support fins would, at times, jam and not freely rotate or slide along the central anchor tube. In addition, the central anchor tube would fill-up with debris and require cleaning before storage or re-use. These difficulties can be overcome by use of corrosion resistent alloys and re-design of the central tube.

The drive point anchors functioned well with corrosion of the cast iron drive point not seriously affecting the utility of the anchor.

The lever anchor puller developed to retrieve drive point anchors worked extremely well. The effort required to remove these anchors was reduced to approximately the same level as that required to remove the screw-in anchors. (Figure 6).

Adjustment of ropes connecting anchors to the mat anchor rope was less troublesome than during the first test. A rapid adjustment device, capable of use under the conditions to be encountered, is still considered desirable.

Vehicle Performance Observations

All the changes made to the vehicle during the period between the first and second on-site tests resulted in anticipated improved operation at the second test. The changes are presented in Section V of this report. The vehicle performed the tasks of transporting, deploying, squeeze roller cleaning, and winding-up beach protection mats well. Figure 7 shows the threading of a beach protection mat by the vehicle at the second on-site test.

Additional improvements in the vehicle are, of course, possible. However, they would be more appropriately undertaken as a complete re-design of the beach protection vehicle rather than as additions or modifications to the present vehicle. Among such additional improvements are:

1. Change from the current 26 hp two-cycle gasoline engine which has poor torque-speed characteristics to a four-cycle gasoline or diesel engine capable of governor controlled operation over a wide output speed range.

2. Re-design entrance slot squeeze roller system such that the beach protection mat passes over a large idling roller enters the squeeze rollers on a down hill slope.

3. Add a mechanical brush to the cleaning system to remove silt, sand, etc., from the top mat surface prior to cleaning.

BEGIN FIRST LINE OF TEXT HERE
TYPING GUIDE SHEET
CENTER OF PAGE
TOP OF IMAGE AREA
DROPPED HEAD: BEGIN SECTIONS HERE

4. Incorporate features to allow manual removal of the beach protection mat from the vehicle at any time during the cleaning operation.

5. Incorporate larger liquid storage and a liquid transfer pump into the vehicle.

6. Replace the vehicle with a beach protection pod unit which is rapidly mounted in the bucket of a scoop loader and uses power from the loader's hydraulic system to clean and wind-up beach protection mats.

Operational Observations

Although the on-site testing done during this feasibility study was not performed under conditions of an oil spill emergency, an observation relative to personnel requirements to operate the beach protection system is in order. The minimum number of persons trained in operation of the system needed on site is two. One should be experienced in the area of vehicle operation; the other should be responisble for supervising both the operational personnel and the deployment of beach protection materials at the site.

8-1/8"
BEGIN LAST LINE OF TEXT
BOTTOM OF IMAGE AREA, OUTSIDE DIMENSION FOR TABLES AND ILLUSTRATIONS
3/8"

EPA-287 (Cin.)
(4-76)

Figure 6. Screw-in anchor insertion and removal.

Figure 7. Threading a beach protection mat into the modified vehicle.

BEGIN FIRST LINE OF TEXT HERE
TYPING GUIDE SHEET
CENTER OF PAGE
TOP OF IMAGE AREA
DROPPED HEAD: BEGIN SECTIONS HERE

VII. REFERENCES

1. Nadeau, R. J., and T. H. Roush. Biological Effects of Oil Pollution, Selected Bibliography II. Environmental Protection Agency, Cincinnati, Ohio. Publication Number EPA-R2-72-055. November 1972. 62p.

2. Blumer, M., et al. The West Falmouth Oil Spill. Woods Hole Oceanographic Institution. Springfield, Va. Publication Number AD 713-947. U.S. Dept. of Commerce. September 1970. 32p.

3. The Assessment of Social Impacts of Oil Spills. An Invitational Symposium of The Institute on Man and Science, Rensselaerville, New York and U.S. Environmental Protection Agency. September 25-28, 1973. 54p.

4. Oil Pollution Liability and Financial Responsibility. A Report to the President and the Congress. Department of Transportation and U.S. Coast Guard, Washington, D.C. December 1970. 22p.

5. Guide to Water Cleanup, Materials and Methods. Arthur D. Little, Inc., Cambridge, Mass. 1974. 350p.

6. Lindenmuth, W. T., et al. Analysis and Model Tests to Determine Forces and Motions of an Oil Retentaion Boom. Hydronautics, Inc. Springfield, Va. Publication Number AD 702 513. U.S. Dept. of Commerce. January 1970 256p.

7. Lindenmuth, W.T., et al. Analysis and Model Tests to Determine Forces and Motions of an Oil Retention Boom. Hydronautics, Inc. Springfield, Va. Publication Number AD 702 513. U.S. Dept. of Commerce. January 1970 256 p.

8. Miller, E. L. Stephens, and J. Ricklis. Development and Preliminary Design of a Sorbent-Oil Recovery System. U.S. Environmental Protection Agency, Washington, D. C. Publication Number EPA-R2-73-156. January 1973. 192p.

9. Cochran, R. A., J. P. Fraser, D. P. Hemphill, J. P. Oxenham, and P. R. Scott. An Oil Recovery System Utilizing Polyurethane Foam-A. Feasibility Study. Environmental Protection Agency, Washington D. C. Publication Number EPA-670/2-73-084. October 1973. 199p.

BOTTOM OF IMAGE AREA; OUTSIDE DIMENSION FOR TABLES AND ILLUSTRATIONS
BEGIN LAST LINE OF TEXT

3/8"
PAGE NUMBER
EPA-267 (Cin.) (4-76)

BEGIN FIRST LINE OF TEXT HERE
TYPING GUIDE SHEET
CENTER OF PAGE
TOP OF IMAGE AREA
DROPPED HEAD: BEGIN SECTIONS HERE

10. Henager, C. H., and J. D. Smith. Concept Evaluation: Recovery of Floating Oil Using Polyurethane Foam Sorbent. U. S. Environmental Protection Agency. Washington, D. C. Publication Number EPA-R2-72-049. September 1972. 97p.

11. Gumtz, G. D., and T. P. Meloy. Oil Recovery System Using Sorbent Material. U. S. Environmental Protection Agency, Washington, D.C. Publication Number EPA-670/2-73-068. September 1973. 159p.

12. Agnew, R. W. A Free Floating Endless Belt Oil Skimmer. U. S. Environmental Protection Agency, Washington, D. D. Publication Number EPA-R2-72-006. August 1972. 93p.

13. Gumtz, G. D. Restoration of Beaches Contaminated by Oil. U. S. Environmental Protection Agency, Washington, D.C. Publication Number EPA-R2-72-045. September 1972. 138 p.

14. Dolan, F. X., and J. P. Bowersox. Development of a Mobile System for Cleaning Oil-Contaminated Beaches. U. S. Environmental Protection Agency, Washington, D.C. Publicatio Number EPA-R2-73-233. May 1973. 92 p.

15. Evaluation of Selected Earthmoving Equipment for the Restoration of Oil-Contaminated Beaches. URS Research Company. Washington, D. C. Publication Number 15080EOS 10/70-1. Department of the Interior. October 1970. 170 p.

16. Feasibility Analysis of Incinerator Systems for Restoration of Oil Contaminated Beaches. Envirogenics Co. Washington, D. C. Publication Number 15080DXE11/70. Department of the Interior. November 1970. 74p.

17. Thomas Register. New York,Thomas Publishing Company. 1973. p. 6499-6509, 7726-7727.

BEGIN LAST LINE OF TEXT
BOTTOM OF IMAGE AREA OUTSIDE DIMENSION FOR TABLES AND ILLUSTRATIONS
3/8"

PAGE NUMBER
EPA-287 (Cin.) (4-76)